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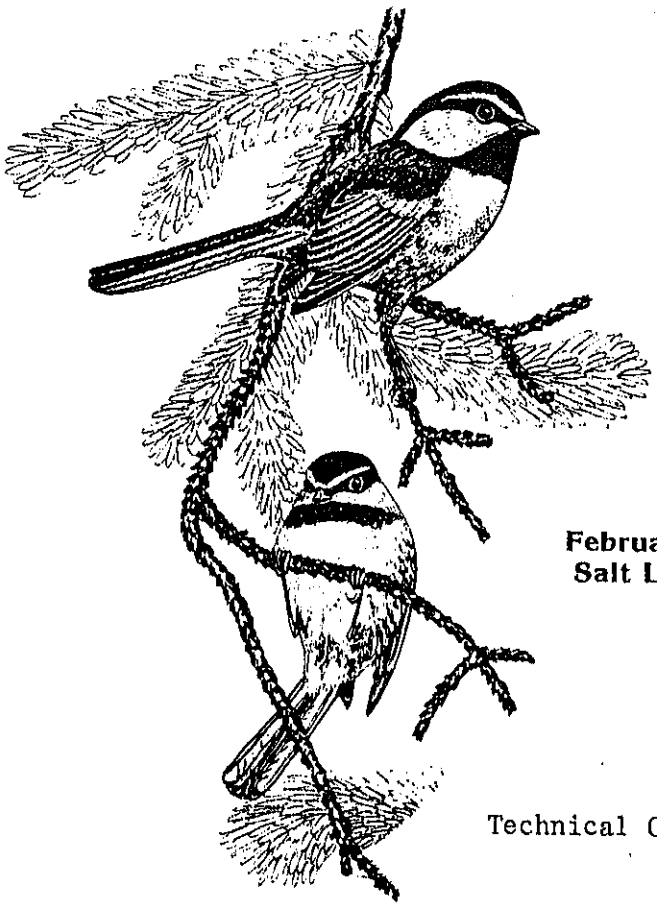
MANAGEMENT OF WESTERN FORESTS AND GRASSLANDS FOR NONGAME BIRDS



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Technical Coordinator: Richard M. DeGraff
Principal Research Wildlife Biologist, Northeastern Forest Experiment Station, and Chairman, National Nongame Bird Steering Committee

Proceedings Compiled by: Richard M. DeGraff
and
Nancy G. Tilghman
Research Wildlife Biologist, Northeastern Forest Experiment Station

Intermountain Forest and Range Experiment Station,
Rocky Mountain Forest and Range Experiment Station,
and Intermountain Region
U.S. Department of Agriculture, Forest Service
Ogden, Utah 84401

PREFACE

In May 1975 a symposium was held in Tucson, Arizona, on the management of forest and range habitats for nongame birds. That landmark meeting brought together avian ecologists and forest resource managers to discuss various aspects of common concerns. That national symposium pointed to the need for both professions to begin to work together to solve the problems of meeting avian habitat needs while managing other forest resources. It was agreed that a series of regional workshops should be conducted to present the best information available on the avian communities of the major forest types and rangelands of the United States. The objective of the series would be to ensure that avian habitat requirements are considered in forest and range management practices, and that the natural bird communities of each forest and range type and successional stages are maintained.

To that end, the National Nongame Bird Steering Committee was formed to sponsor regional workshops presenting the state-of-the-art of nongame bird research and management in various ecoregions of the United States. The first workshop was held in Portland, Oregon, February 7-9, 1977, entitled, "Nongame Bird Habitat Management in the Coniferous Forests of the Western United States."

The second workshop in the series, "Management of Southern Forests for Nongame Birds," held January 24-26, 1978, in Atlanta, Georgia, presented bird habitat research results and management techniques for all major habitat types in the southern and southeastern United States.

The third workshop, "Management of North Central and Northeastern Forests for Nongame Birds," held January 23-25, 1979, in Minneapolis, Minnesota, presented information on avian communities and their management in the forest types of the northeastern quarter of the country. This fourth and last workshop is jointly hosted by the Intermountain Forest and Range Experiment Station, the Rocky Mountain Forest and Range Experiment Station, the Intermountain, Southwestern, California, and Alaska Regions of the USDA Forest Service, and the State and Private Forestry Office of the Intermountain Region.

The Forest Service was joined by the other members of the National Nongame Bird Steering Committee in sponsoring this workshop. Its members include:

USDA Forest Service
USDA Soil Conservation Service
U.S. Department of the Interior, Fish and Wildlife Service
U.S. Department of the Interior, Bureau of Land Management
National Wildlife Federation
The Wildlife Society
Wildlife Management Institute
National Audubon Society
International Association of Wildlife Conservation Agencies

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BIRDS IN FOREST AND RANGE ECOSYSTEMS

Moderator: DOUGLAS DAY
Utah Division of Wildlife Resources
Salt Lake City, Utah

KEYNOTE ADDRESS

RESOURCE MANAGEMENT--A BROAD VIEW

R. Max Peterson

Chief
USDA Forest Service

ABSTRACT

Wildlife and fish habitat management is a part of the Forest Service's land management planning under the National Forest Management Act and the Resources Planning Act. The philosophy, the policy and the planning mechanisms now exist to simultaneously benefit wildlife and fish and other forest and rangeland resources in the National Forest System.

As keynote speaker, I am not here to present a paper on major new research findings, nor to detail specific activities to promote wildlife habitat on the National Forests, nor to discuss the excellent State-Federal relationships concerning wildlife. I want instead to describe to you a very broad planning process as the basis for all Forest Service resource decisions, and to discuss major changes that I see in resource management and philosophy. One of these, I'm happy to say, is fish and wildlife management, including nongame birds, is now a key part of our resource planning.

Before I do that, I would like to congratulate those who put this workshop together for the breadth and depth of the subject matter being covered. The participation of Federal and State agencies as well as professional wildlife organizations and citizen conservation groups attests to both the breadth of intent in the subject matter and the importance of a professional approach to making progress.

As for management of National Forests, I can do no better than to quote the National Forest Management Act of 1976, the mandate that Congress has given us for managing the National Forests: "Insure consideration of the economic and environmental aspects of various systems of renewable resource management, including the related systems of silviculture and protection of forest resources, to provide for outdoor recreation (including wilderness), range, timber, watershed, wildlife, and fish."

To do this, we will: "Provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives...", meaning, the objectives of the land management plan for that forest.

I think you get the idea. The National Forest Management Act, and its subsequent regulations, is one of the most specific mandates we have ever had.

It calls, in short, for a completely integrated wildlife program; one that provides diversity, and goes beyond merely favoring or encouraging certain species. We mean a holistic look at all resource management, including the wildlife and fish program. And we gladly accept the challenges.

Fish and wildlife habitat management must be more than a slogan or good intention. Fish and wildlife management is a fully functioning part of our land management planning. One of the reasons that wildlife now plays a strong role in multiple use management is the advancement of knowledge that many of you here today have achieved. An excellent example is the first Nongame Bird Symposium, held in 1975. It was Dixie Smith who did most of the pioneering for this whole effort. He had the original idea. He set up the steering committee. He was the ringleader for the original Symposium. Then, Dick DeGraaf picked up the leadership, and brought us through regional symposia in Portland, Altanta,Minneapolis,and now Salt Lake City. I want to thank those of you who have contributed so much. The fact that proceedings were issued immediately after the first Symposium is testimony to your dedication to taking research results and putting them into practice in the forest. Sometimes we forget that the role of knowledge is to improve what we do--and to lose that value when we don't translate knowledge into action.

And, speaking of translating words and knowledge into action, that is exactly the role of land management planning on the National Forests. Every resource use, consideration, trade-off, and so on, must begin at this point. As you probably know, we are now doing comprehensive land management plans--which emphatically must include all resource uses--for each National Forest. The plans must be done by the end of 1985, but we are working hard to complete them earlier, in order to tie in as closely as possible with the 1985 Resources Planning Act program update. We expect that the Secretary's long-range program recommendations for Forest Service activities together with the 1980 Assessment covering all the Nation's public and private forests and rangelands will go to Congress soon. After than, the Program will be updated in five years, and the Assessment every ten years. Basically, the Assessment projects demands and supplies for all the renewable resources. The Program then sets goals for Forest Service programs for Research, Cooperative programs and management of National Forests to meet these demands. For instance, a number of alternative goals were considered in the draft Program. The alternative outline went from intensive management of the National Forests for a number of resources, to an alternative which would emphasize providing more of the production from private lands. I can't tell you the specifics we are recommending, since the documents have not yet gone to Congress. But I <u>can</u> tell you how the program was developed, and tell you it does deal signigicantly with fish and wildlife programs.

The Program itself was built from the field up. The National goals will be disaggregated from the National Program back to regional programs, and then to the Forest level. I must emphasize that the Program is not the product of a Washington think-tank approach--everything set out in the Program is possible, and is developed from information received from all levels of the Service and from many sources outside.

The RPA Program and the National Forest land management plans go hand in hand. I cannot overemphasize the importance of this. The key to realistic resource

management is one comprehensive, integrated land management plan. Previously, we have had detailed single-resource plans, with mechanisms for coordination. Sometimes it worked very well, sometimes it didn't work as well.

We are doing now what has been termed holistic management. This simply means that we are looking at the whole picture rather than pieces. You wildlife professionals know the value of this, and the inherent truth that anything done in the forest environment affects wildlife, whether it's planned that way or not. So, why not do planning for all resources at one time, and benefit the wildlife and fish, the recreationist, the public that needs timber, and many others as well? Or, if we can't benefit them all at once, at least we can make a knowledgeable choice, rather than not even being aware than we are making choices.

Let's, for once, start with the recognition that there's a great deal of resource management that is complementary. If not complementary, many resource activities can be made compatible. Early on in the wildlife business many of us tended to look at all habitat change as bad. We were operating in a trade-off or confrontation mode. We now recognize that it is possible to manage forests to benefit a number of responses, and a number of public demands. For example, insectivorous birds feed on insects that can be damaging to a forest. Timber can be managed to accommodate these birds. Our snag policy is another example of managing the forest resource for both timber and wildlife.

I might add that, in some ways, the end result is more important than the individual reasons for each management decision. A lot of activities that benefit wildlife are not shown in the budget column under wildlife. It doesn't matter whether the management is direct or indirect. The wildlife doesn't know the difference. It just accepts that benefit.

Wildlife and timber management have been traditionally claimed as being at cross purposes. I do not accept this any more than I accept the cliche that good timber management is good wildlife management. I hope that there is more compatibility in timber and wildlife management than most people will admit, or care to admit. I am asking all of us here to break some traditional prejudices and work together for the best management for the total forest resource. To do so, I realize, will call for more flexibility by many different professions than has been traditional. In the West particularly, there has been more focus on the big game, such as deer and elk. I see this changing. There is increasing awareness and concern for bird habitats as well.

Symposia such as this one can help break through what has been the greatest barrier to managing wildlife habitat on the same level as many other resources. Very simply, we have had a lot of information on timber for many years--perhaps because forestry was one of the earliest resource professions, and it focused on the vegetation aspect. Now, we are getting much more information on wildlife, but we still need more. The wildlife profession deserves credit for the way they are developing better ways of predicting results of actions and positive steps we can take to promote habitat of various groupings of wildlife and fish species. We have to go with some grouping system because we can't deal with 200 to 300 different species on any one area.

Endangered species habitat has been emphasized for some years now, but we have to keep it in perspective. Species such as the California Condor, the Kirtland's Warbler, and the Red-cockaded Woodpecker have received a great deal of work and publicity. But, we must also have diversity.

We believe that the key to providing habitat for wildlife species is habitat diversity--as stated in the National Forest Management Act. Today, we have specific policies for wildlife and fish. These policies are now being sharpened even more.

We recognize inherent relationships within the wildlife resource. Everything we do as resource managers will benefit some species, be detrimental for some, and, perhaps, not even affect some. The key is to plan for diversity, of both plants and wildlife, over areas of land.

There are trade-offs among resources. We cannot deny this. And two of the toughest trade-offs to plan for right now involve old growth timber in the West and riparian habitats. We recognize this, will acknowledge it in our planning, and we ask for your help as land management plans are drawn up for each National Forest. Both trade-offs are important to nongame birds, and to long-term multiple uses of our forests and rangelands. We need more information about the habitat needs of some species. We need to know more about the adaptability of other species. This is really crucial, because in many cases we know that a certain management action will cause a certain effect on habitat. But, at what point does it affect the populations of the species?

I have intentionally saved one of the most important areas--Research--until last.

I want to emphasize how much Forest Service research involves wildlife, even though a particular project may not appear in the wildlife column of the budget. For instance, the Intermountain Station is doing a good deal of research on reclaiming disturbed lands, and a major consideration is reclaiming these lands for wildlife species including nongame birds. In Provo, Utah, and Boise, Idaho, a shrub improvement project on disturbed lands--and the value of those shrubs to wildlife is one of the major criteria.

Another project out of Boise is studying the effects of livestock grazing systems on the aquatic system. Needless to say, anadromous fish and all the species associated with riparian habitats will benefit greatly from these and other ongoing research studies.

The 1981 budget gives new money for western range research, which will include wildlife considerations.

A major Forest Service research initiative is to integrate fish and wildlife studies with other, broader studies. For instance, research on improving silvicultural systems for the purpose of increasing softwood production relates the impacts of possible increases on other resources, including wildlife.

From now on, most of our Forest Service research will follow this broad concept, so that we can better relate it to achieving overall multiple use objectives. We consider this an important way to utilize research dollars.

I have used a few specific Forest Service examples; yet I in no way mean to imply that any one agency or group is carrying the ball by itself. Individually, none of us can do the total job. We are, in a very real sense, pioneering in wildlife management. We need our collective knowledge and experience. For example, the Soil Conservation Services' Resource Conservation Act Appraisal and long term program hold major promise to improve wildlife habitat on the Nation's farmlands.

I am asking you to look realistically at the areas of potential conflict. I see some looming ahead, particularly in the energy arena.

I ask you also to look at the total resource and the sum total of demands and opportunities. The RPA Assessment shows that all demands on the forest resources--for water, recreation, fish and wildlife, range, and timber, will increase greatly over the next 50 years. In fact, most demands will double. Some will even triple. The Program that we present to Congress shortly will be possible, from the economic, social, and environmental vantages. I know that what it calls for can be done. Now, we need to go out and make sure that we have specific plans to do it, and then put our plans into action. We have the philosophy, the policy, and the planning mechanisms that wildlife professionals and other resource specialists have been wanting for years. Now, let's make sure that we use them to benefit the entire forest and rangeland resource.

THE ROLE OF BIRDS IN WESTERN COMMUNITIES

Steven R. Peterson

Head
Department of Wildlife
University of Idaho
Moscow

ABSTRACT

Birds have a variety of roles in western communities. Individual birds, populations, or species may have one or several roles at the same time, or roles may be different at different times. These roles are examined from three viewpoints: economic, aesthetic, and ecologic. Management decisions involving birds should stress our desire to retain intact communities as well as the need to maintain the various roles discussed.

KEYWORDS: birds, roles, western communities.

[illegible] for example, endangered species, these are difficult questions to satisfy with tangible evidence.

[illegible] paper I have reviewed the literature and summarized my thoughts into three [illegible] concerning the role of birds: the economic role, an aesthetic role, and birds' ecological role. After presenting the evidence regarding these roles, I [illegible] by asking a series of speculative questions aimed at [illegible] thought on the subject.

THE ECONOMIC ROLE

[illegible] of the literature on the role of birds has been developed purely from [illegible]. The food habits of birds have always been a popular [illegible]. When this information helps land managers to define limiting [illegible] in the production of trees for people, or forage for livestock, the data be[illegible]. As I view it, the economic role of birds emerges in two [illegible]: (1) [illegible] insect control or regulation; and (2) seed consumption and [illegible].

Birds [illegible] additional [illegible] insect populations through consumption of [illegible], consumption of parasitized larvae, or consumption of parasitic [illegible]. [illegible] consumption of various coniferous insect pests, including the spruce budworm (Choristoneura fumiferana [illegible]), Engelmann spruce beetle (Dendroctonus obesus), jack [illegible] (Neodiprion pinetopsis [illegible]), and others has been well documented (Beal 1911; [illegible]; Baldwin 1968; Kaplan 1972; Otvos 1979).

Avian predation on insect populations is similar to that described for several [illegible] in that interactions such as the lynx (Lynx canadensis) - snowshoe hare (Lepus americanus) and Arctic fox (Alopex lagopus) - brown lemming (Lemmus [illegible]). The numerical effect is greatest at epidemic levels or lower (Kaplan 1972), and when a particular species of insect prey is abundant, numerous avian predators will consume it. Since the insect reaches pamphidemic numbers, avian [illegible] [illegible] and [illegible] simply cannot cope with the insects' reproductive potential. [illegible] most insectivorous birds are facultative feeders, their opportunistic feeding behavior generally acts to dampen oscillations in specific areas before insects reach outbreak proportions (McFarlane 1976). Birds, as predators, can also [illegible] for any insect [illegible]: they may be very selective in eliminating certain [illegible], or they may be relatively nonselective, and take "target" as well as "nontarget" insects. Their primary role then, is really in preventative regulation, rather than definitive control, of a chronic problem (Otvos 1979).

It is becoming more apparent that insectivorous, forest-dwelling birds may be most useful in the winter (Campbell 1974). Even though Baldwin (1968) noted several summer resident passerine birds fed on the emerging stages of insect pests, the birds' potential to regulate their prey is much less than in permanent or winter residents (Wiens 1975). Perhaps in the future we should pay more attention to the needs of wintering birds than we have in the past. Quantitative studies of wintering bird communities, and their role in regulating forest insects, are definitely lacking in the literature.

Birds also directly affect our western communities in an economic way through their consumption of seeds. Hagar (1960) found that species such as pine siskin (Spinus pinus), purple finch (Carpodacus purpureus), red crossbill (Loxia curvirostra) and others can directly affect regeneration when they attack pine cones around the edges of clearcuts. In addition, ground feeding granivorous birds such as the junco (Junco hyemalis) and mountain quail (Oreortyx pictus) can hypothetically consume up to 17 percent of the seed that is likely to fall on a cut during a good seed year.

Granivorous birds, like their insectivorous counterparts, are probably opportunistic and respond similarly to available food sources (Wiens 1975).

Seed dispersal can also be enhanced when ingested by birds. Proctor (1968) has documented the viability of hard seeds excreted from migratory birds. Further evidence of excreted viable seeds can be seen along fence rows and powerlines used as perching sites by birds. Several woodland species (e.g. woodpeckers, jays and nuthatches, Sitta spp.), exhibit hoarding behavior when food is abundant, and thus contribute to the dispersal of seeds in addition to their consumption of the resource. Thus birds can, and do, affect our efforts to manage forests and rangelands. In many cases their effects may be subtle, but very significant, economically.

THE AESTHETIC ROLE

Birds surely have an important aesthetic role in western communities but assessment often yields intangible and variable results. Endangered birds, such as the whooping crane (Grus americana) at Aransas, bald eagles (Haliaeetus leucocephalus) in Glacier National Park, or the California condor (Gymnogyps californianus) in the mountains near Santa Barbara, California, are extremely valuable aesthetically because they are difficult to see, and people will spend considerable sums just for the chance opportunity of sighting one. Granted, the worth of this observation will vary with the individual, but is assessment of the spectator sport called "bird watching" any different than the measurement of other common spectator sports? Professional football is a spectator sport worth millions of dollars every year, and yet the value of a football game varies with the observer. The sport is not unique, but it is very popular and people are willing to pay a relatively high price to see the games. Viewing Mt. Rushmore, or exhibits in the San Diego Zoo are unique spectator sports but the experience also varies with the individual. The basic aesthetic values of these items are measured at the gate by the number of spectators who come thru the turnstile. These common parameters of uniqueness, participation, and monetary value, make measurement of the aesthetic value of birds similar to other spectator sports.

Birds that drill or forage in the wood and bark of trees change the peripheral environment of those plants. When sapsuckers (Syphyrapicus spp.) drill holes in trees to drink sap, cracks can form between the annual rings (Shigo 1973) and permit fungal spores to enter (Otvos 1979). Spores of the chestnut blight fungus (Endothia parasitica (Murr)) have been found in downy woodpeckers (Dendrocopus pubescens; Heald 1933) and brown rot fungi have been associated with several birds. When woodpeckers flake bark from trees they not only remove the insects available to them, but they can also change the microhabitat of their prey in an adverse way (Otvos 1979). Flaking causes the thickness of the bark to be reduced and the insect broods can either be killed directly from changes in temperature or moisture, or can be parasitized by hymenopterous insects with short ovipositors (Massey and Wygant 1954; Otvos 1965).

In addition to causing direct and indirect changes in forest insect populations and their environment, birds may assist in the spread of insect pathogens. Franz et al (1955) and Entwistle et al (1977) examined the spread of entomopathogenic viruses by birds after they ate infected insects. In Wales nearly 40 percent of the bird species contained virus organisms in their feces. Entwistle et al (1977) concluded nonterritorial birds would spread the virus more than territorial birds, and Buse (1977) considered birds to play a relatively minor role in spreading virus diseases into virus-free localities.

Birds probably play a minor role in rangeland ecological processes. Avian species and numbers are relatively few compared to the number of large herbivores generally associated with these communities (Wiens 1973). Presently, we know little about the role birds play in regulating herbivorous insects inhabiting our grasslands, but it is known that insects can influence the translocation of nutrients into the roots of grasses by defoliation. Therefore, if rangeland birds are generally able to keep their insect prey in check, as the literature suggests for their forest-dwelling counterparts, the nutritive condition of rangeland plants may be indirectly affected by bird-insect predator-prey relationships in these areas (Wiens and Dyer 1975). However, when chewing type insects such as the grasshopper go unchecked, and reach panepidemic proportions, they can have the same profound effects on production as forest insect herbivores (Wiens 1973).

OTHER ROLES

Another relatively minor role birds play in western areas is involved with nutrient cycling or transfer. Woodpeckers can indirectly speed up the nutrient cycle in our coniferous forests by causing snags and rotten logs to decompose faster through their feeding activities (Otvos 1979), but Sturges et al (1974) noted the loss of nutrients from eastern hardwood forests by birds is extremely low when compared to other removal processes, such as water runoff. However, when birds consume insects or seeds, nutrients are retained for longer periods of time if the insects were not eaten, and if the birds are migratory, these nutrients may be entirely removed from the system (Wiens and Dyer 1975). Continuous removal of a trace element that is a limiting factor for example in forage production, could eventually cause serious consequences.

Wiens (1973) raised an interesting possibility that, at least in rangeland areas, migratory birds perhaps do not play any role in influencing the function and structure of that ecosystem. Instead, they have evolved as "frills" in a system where food is too plentiful to be fully utilized in the summer and too scarce to support an avian community in the winter. Consequently, in habitats with strong seasonal fluctuations, excess nutritive material is produced in the summer that cannot be fully utilized by the avian consumers during that period (Bourliere and Hadley 1970).

CONCLUSIONS

As land managers and biologists, we are often called upon to assess or give advice on making provisions for avian habitat on a piece of ground. Basically the question revolves around three issues: (1) the need to provide that habitat; (2) the quantity of habitat to be provided; and (3) the cost of providing that habitat. If people are willing to spend money to provide habitat for birds (or keep from harvesting something that is valuable), then it is reasonable to conclude that birds must be worthwhile, or have some useful role in that habitat. But is the converse also true? That is, if people are not willing to provide for the continued existence of birds, such as in a management plan for a particular area, then does this imply that the manager feels the birds are not a useful entity worth saving in that area?

To examine this worth, we can approach the principle of providing for birds from two bounds on the argument: (1) we manage our western habitats (at least public lands) only for birds; or (2) we do not manage for birds at all. The first option is unrealistic because vast essential reserves of gas, oil, coal, minerals, and timber, would be "locked up". Our society simply would not allow it. But what if we chose the latter option, not to manage for birds at all. This says we are willing to allow species to go to extinction - at least in selected areas under our control. This has certainly happened in the past, and will continue into the future for all areas in which the management plan does not give more than just "consideration" or lip service to avian inhabitants.

Let us explore the consequences of option (2) further and examine it from the three broad viewpoints presented previously. From a purely aesthetic viewpoint, if all the birds in western habitats were allowed to disappear, how many people would be adversely affected? No doubt many people would feel remorse, but the lives of few people would be put under severe hardship. Surely the next generation would not miss the birds because they could not miss something they have not experienced.

From a purely economic viewpoint, the conclusion is similar. If at least the insectivorous birds disappeared, there probably would be more frequent and more severe insect outbreaks. But there is no doubt in my mind that technology could find suitable insecticides or virus free strains of plants to counter the situation without birds - it's been happening in agriculture for decades over vast acreages of monoculture crops. This situation is really not much different than intensively managed homogeneous (monoculture) stands of timber, shrubs, or grasses. The job would be even easier if the people who develop and use pesticides did not have to worry about the effects on avian communities.

From an ecological viewpoint, what would happen to the various western habitats, or ecosystems, if the birds disappeared? When an avian species is removed from a specific habitat, the ecosystem is different because there is one less component, but can we measure the effect? Did anything drastic happen to the beech (Fagus spp.) forests in the midwest when the passenger pigeon (Ectopistes migratorius) that darkened the sky some days disappeared? How about Martha's Vineyard when the last heath hen (Tymponuchus c. cupido) died? Will anything catastrophic happen in that California ecosystem if the few remaining condors are allowed to pass on without replacement? I doubt it. Throughout the west, if the birds disappeared, there may be some effects on the mammal community, but how many mammals are solely dependent on birds for their livelihood?

The point I have been trying to make here is that, except from a moral viewpoint to preserve what is, it is difficult to demonstrate with tangible or intangible evidence, that maintaining our bird communities is worthwhile. We know that birds

do play a variety of roles and obviously dead birds have no roles. It is also obvious that if we do not provide suitable and adequate habitat, we will lose avian species. The basic question then, is do we want birds to have a role in western habitat, for whatever reason?

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HABITAT SELECTION, SUCCESSION, AND BIRD COMMUNITY ORGANIZATION

Stanley H. Anderson

Migratory Bird and Habitat Research Laboratory
U.S. Fish and Wildlife Service
Laurel, MD 20811

ABSTRACT

Nongame bird community management is suggested based on habitat selection, plant succession, and bird community organization. Suggested forms of stratification of habitat are examined. Factors that indicate habitat selection and bird community organization are shown by means of discriminant function analysis, principal component analysis, and factor analysis. Factors such as habitat size, habitat structure, water impoundment, and edge are related to nongame bird communities.

KEYWORDS: habitat selection, bird community, nongame bird management, stepwise multiple regression, discriminant function analysis, principal component analysis, factor analysis.

INTRODUCTION

Effective management of birds means effective habitat management. Habitat is a term applied to the area where all requisite needs for a species are found. Typically, biologists state that animals "select" their habitat; however, this is not an accurate statement because animals have coevolved with the biotic and abiotic components of an ecosystem. Since there are many variations in the physical environment, many different living assemblages evolve. These groups of organisms then provide their own dynamic structure to the community, which creates further variation in the types of habitat.

Bird species are usually found in habitats where their shelter, feeding, and social needs are satisfied which means that some species are found in more than one habitat type. Thus, for example, chickadees nest in forests but move through forest, edge, and savannah-like habitat to feed.

Furthermore, one must realize that habitat used by birds differs during each season. During the breeding season, concentrations of residents and breeding migrant species defend territories in their breeding habitat. In the fall, most nonbreeding migrants and resident species are found in a variety of habitats. Resident species appear to be more nomadic than during the breeding season, whereas nonbreeding migrants may be flocking and simply stopping for a short period of time. In the winter, many North American habitats have mixed flocks of permanent resident and winter resident species, which move through several habitats seeking food.

In each community, birds have evolved characteristics that allow them to survive. Individual species may have minor variations in different community types. For example, food of the nuthatches found near the Williamette Valley in Oregon differs during the spring, fall, and winter seasons. Likewise, bill size of nuthatches in the forests of the Coast Range differs from that of populations living in the forests of the Cascades (Anderson 1976). Such differences might result in part from structural variation in habitat; however, they are also related to the different species assemblages that are found in different communities.

The present paper examines a technique for looking at the stratification of habitat as the basis for discussion. Examples of methods used to determine habitat features associated with individual species are given. Finally, community changes known to be associated with changes in bird populations are discussed and related to the management of nongame birds.

STRATIFICATION

To effectively manage birds in different communities it is necessary to have some form of subdivision or stratification of the environment into ecoregions in order to associate bird communities with habitat structure and successional stages. At the Migratory Bird and Habitat Research Laboratory, we have developed a stratification based in part on results of the Breeding Bird Survey (Fig. 1).

The method behind stratification was that each species of bird has its own geographic limits and within these limits are several zones of abundance representing availability of suitable habitats. In mountainous areas, there occur discrete zonal boundaries to vegetation types that result from differences in temperature, precipitation, or wind speed. Typically the abundance of many species of birds changes abruptly across such boundaries. In flat country, boundaries are more obscure and in many instances very irregular, often extending for miles along a stream valley where differences in soil type or moisture support habitats not found a short distance on either side of the stream.

Because bird distribution and abundance, particularly in the breeding season, is so strongly influenced by habitat the use of ecological rather than political boundaries is most logical. Ecological boundaries are based largely on John Aldrich's (1963) map of Life Areas of North America, developed for his paper on Geographic Orientation of American Tetraonidae. There have since been many minor adjustments in strata boundaries. Such refinements in the United States have come largely from "Physiogeography of Eastern United States" (Fenneman 1938), "Natural Land Use Areas of the United States" (Marsckner 1933), "Potential Natural Vegetation" (Kuchler 1965), and various publications for individual states. Canadian boundary refinements have come from Dr. A. J. Erskine of Canadian Wildlife Service and from published maps of individual provinces.

The name of each stratum as defined by Breeding Bird Survey (BBS) data is shown in Table 1.

These strata are grouped into eight larger regions which contain broadly similar habitat types. The regions are as follows:

1 - Southeastern Mixed Forest
2 - Eastern Deciduous Forest
3 - Northern Coniferous Forest
4 - Prairie and Plains
5 - Western Mountains
6 - Pacific Slope
7 - Arid Interior
8 - Tundra

In the western part of the United States, for example, we can see that the Great Plains, Western Mountains, Arid Interior, and Pacific Slope are each broken down into several distinctive BBS strata.

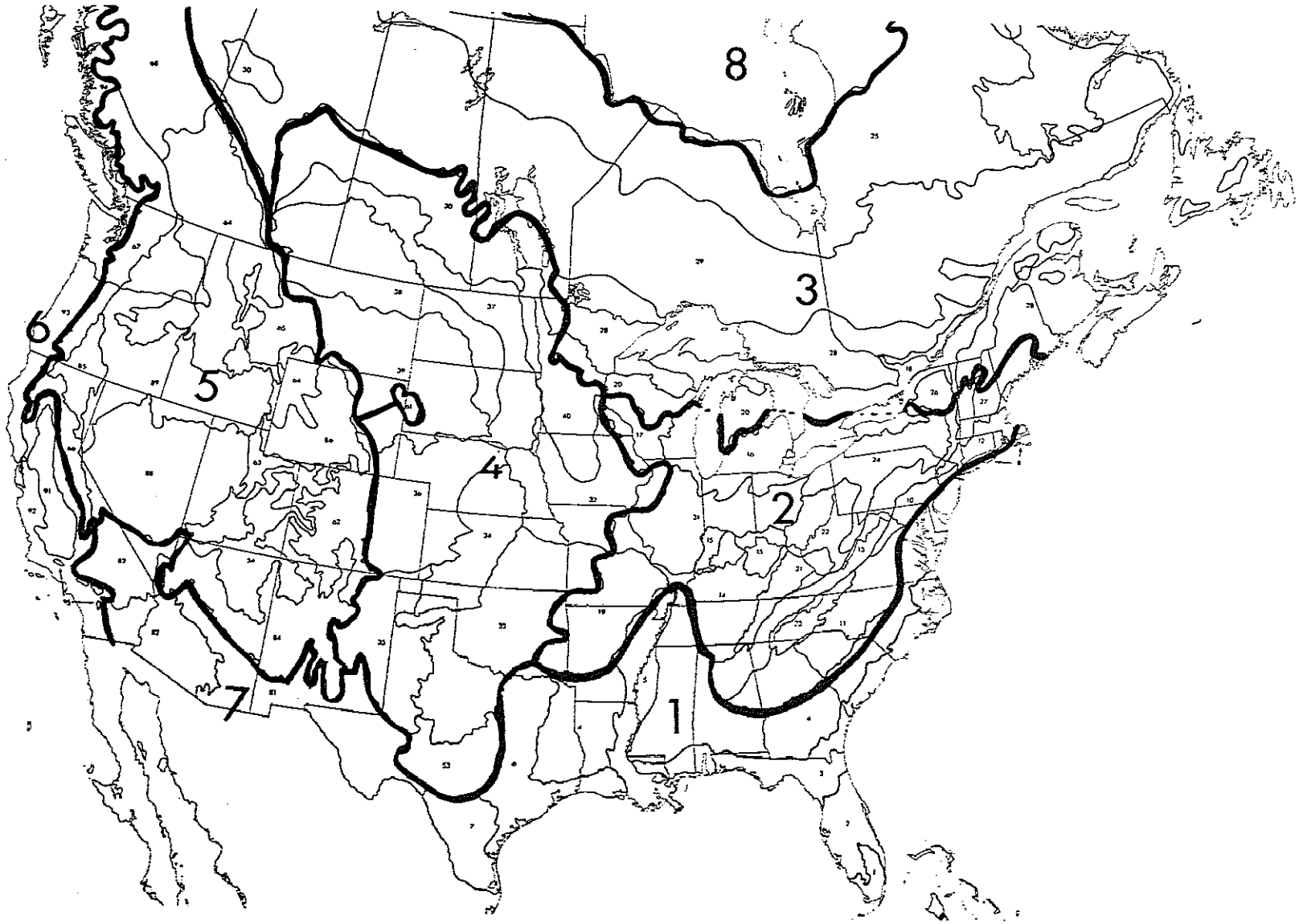

Figure 1.--Physiogeographic strata in the United States and Canada. See Table 1 for stratum name.

TABLE 1.--Breeding Bird Survey Strata (1979).

SOUTHEASTERN MIXED FOREST

01 Sub-tropical
02 Floridian Section
03 Lower Coastal Plain
04 Upper Coastal Plain
05 Mississippi Alluvial Plain
06 West Gulf Coastal Plain
07 Nueces Plain
08 Glaciated Coastal Plain

EASTERN DECIDUOUS FOREST

10 Northern Piedmont
11 Southern Piedmont
12 Southern New England
13 Ridge and Valley
14 Highland Rim
15 Lexington Plain
16 Great Lakes Plain
17 Wisconsin Driftless Area
18 St. Lawrence Plain
19 Ozark-Ouachita
20 Great Lakes Pine Belt

NORTHERN CONIFEROUS FOREST

21 Cumberland Plateau
22 Kanawha Plateau
23 Blue Ridge Mountains
24 Allegheny Plateau
25 Open Boreal Forest
26 Adirondack Mountains
27 Northern Hardwoods
28 Spruce-Hardwood Forest
29 Closed Boreal Forest
30 Aspen Parklands

PRAIRIE AND PLAINS

31 Till Plains
32 Dissected Till Plains
33 Osage Plains
34 High Plains Border
35 Staked Plains-Pecos Valley
36 High Plains
37 Prairie Pothole Section
38 Missouri Plateau-Glaciated
39 Missouri Plateau-Unglaciated
40 Black Prairie
53 Edwards Plateau
54 Colorado Plateaus & Canyonland

WESTERN MOUNTAINS

61 Black Hills
62 Southern Rocky Mountains
63 High Plateaus of Utah
64 Central Rocky Mountains
65 Dissected Rockies
66 Sierra-Trinity Mountains
67 Cascade Mountains
68 Canadian Rockies

ARID INTERIOR

81 Mexican Highlands
82 Southern Sonoran Desert
83 Northern Sonoran Desert
84 Pinyon-Juniper Woodland
85 Klamath-Pitt Plateau
86 Wyoming Basin
88 Great Basin
89 Columbia Plateau

PACIFIC SLOPE

91 Central Valley
92 California Foothills
93 Southern Humid Coastal Belt
94 Northern Humid Coastal Belt
95 Southern California Mountains

HABITAT ASSOCIATIONS OF NONGAME BIRD SPECIES

Statistical Techniques

Birds can be observed in a variety of habitat types. In order to develop species management plans, it is necessary to explain which features of the habitat are associated most frequently with each species of bird. A number of different techniques have been tested to associate birds with habitat structure. These range from a quantitative description of the vegetation and physical environment to statistical analyses showing which particular features are associated with each bird species. It is always necessary to sample bird abundance and determine habitat factors that are related to the avian community. The following are a few of these techniques, showing how they relate to community management practices.

Stepwise multiple regression, which uses the abundance of bird species as dependent variables and habitat measurements as independent variables in a regression equation, can be used to indicate which of the habitat variables can best be used to predict bird species abundance (Sturman 1968, Robbins 1978). The variables are added into a regression equation in the order in which they increase the multiple correlation coefficient. The variable that most reduces the residual variation in species abundance around the least squares regression line is added first; the variable that most reduces the variation when considered with the first variable is added second; the third variable considered in conjunction with the first two which most reduces the variation is added next; and so on (Barr et al. 1976). Habitat variables continue to be entered into the equation until no more significant reduction in variation is possible. Thus, a different number of variables acting together are significantly correlated with each bird species.

In the Oregon white oak stands the Black-capped Chickadee[1]/ was shown by stepwise multiple regression to be associated with the number of trees per acre taller than 60 feet, canopy volume per acre, the DBH, the total canopy cover, and the amount of space (distance between trees) (Anderson 1970). The White-breasted Nuthatch in these forest stands was associated with the length of secondary branches coming off the major branches in the tree, the total amount of vegetation in the upper layer, and the distance between trees. In Douglas-fir forests, the Chestnut-backed Chickadee was associated with the amount of space found between the trunk of the tree and the foliage, the type of bark, the number of dead twigs, and the total trees per acre. The Red-breasted Nuthatch in Douglas fir was associated with canopy volume, canopy cover, the number of snags, and the number of trees taller than 60 feet. By comparison, the Brown Creeper, which was found in both the oak and fir, was associated with the same four factors in each habitat; in the oak forest the sequence was: the distance between the trunk of the tree and the branches, the total trees per acre, the distance from the ground to the top of the trunk, and the average height of trees. In the conifers, the sequence of the last two factors was reversed.

Another technique that has been useful in determining the relationship between bird species and habitat structure is discriminant function analysis (Anderson and Shugart 1974, Bertin 1977, Noon in press). Stepwise multiple regression deals with the interdependence of variables and each variable is dependent on how much it in combination with the other variables reduces the residual variation in abundance around the regression line. Discriminant function analysis selects a subset of habitat features which best distinquishes habitats of two or more species. If the groups in the analyses are based on the presence or absence of a particular bird

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[1]/See Appendix I for scientific names of bird species discussed in paper.

species, specific habitat requirements may emerge. In a study in an east Tennessee forest, Anderson and Shugart (1974) found the White-breasted Nuthatch to be associated with total amount of foliage and branches, biomass of trees 1.2 to 8.4 cm DBH, while Downy Woodpeckers were associated with the total number of saplings present.

Habitat Use

Biologists recognize that specific habitat features of the forest can be associated with different bird species and thus provide information necessary to manage that species. Biologists also must realize that within the community birds use habitats in different ways. For example, both vertical and temporal stratification occur in a breeding bird community in a forest system (Anderson et al. 1979). When species comparisons are made, it is possible to show how different periods of activity or different forms of vertical stratification permit birds to use communities in different manners. Cody (1968) discussed how horizontal, vertical, and temporal habitat selection and food specialization allow species to coexist in different communities.

Habitat features, as well as species behavior patterns, can be used to discuss specific forms of habitat selection and bird distribution. Noon (in press) showed how a guild of five thrush species that are sympatric on large mountains in the northeastern United States had distinct distribution patterns along elevation gradients. Guild composition and distributions shift with changes in the habitat as one moves southward along the Appalachian Mountain chain. Thus the natural evolution and turnover of plant communities along the mountain gradient has resulted in variation in bird species occupying that gradient.

Succession

Community succession and bird populations respond to natural shifts in structure of avian habitat. In previous discussion I showed that changes in the total canopy volume, the degree of openness, or other features of the habitat result in changes in populations of birds because the features with which they are associated may no longer be present. This type of study in a successional sequence provides an example of the use of community types in managing nongame bird populations.

In western Oregon, natural successional sequence moves from an open oak savannah to a dense oak forest into the more coniferous Douglas-fir (Fig. 2). In the Oregon white oak, the Black-capped Chickadee, White-breasted Nuthatch, Bewick's Wren, Bushtit, Orange-crowned Warbler, MacGillivray's Warbler, and Wilson's Warbler are common. Looking at the coniferous forest, we find that Chestnut-backed Chickadee, Red-breasted Nuthatch, Brown Creeper, Winter Wren, Hermit Warbler, Western Tanager, and Oregon Junco are the more common species (Tables 2 and 3).

Thus studies of succession indicate that there are distinct groups of birds associated with each type of community in each successional sequence. Overlap occurs as different seral stages are reached; however, to maintain a good variety of nongame communities it is necessary to have representatives of each stage. Frequently human disturbance adds to habitat diversity and allows managers to better maintain a series of communities. Thus fire, logging, and brush clearing projects can all be planned in the context of natural succession.

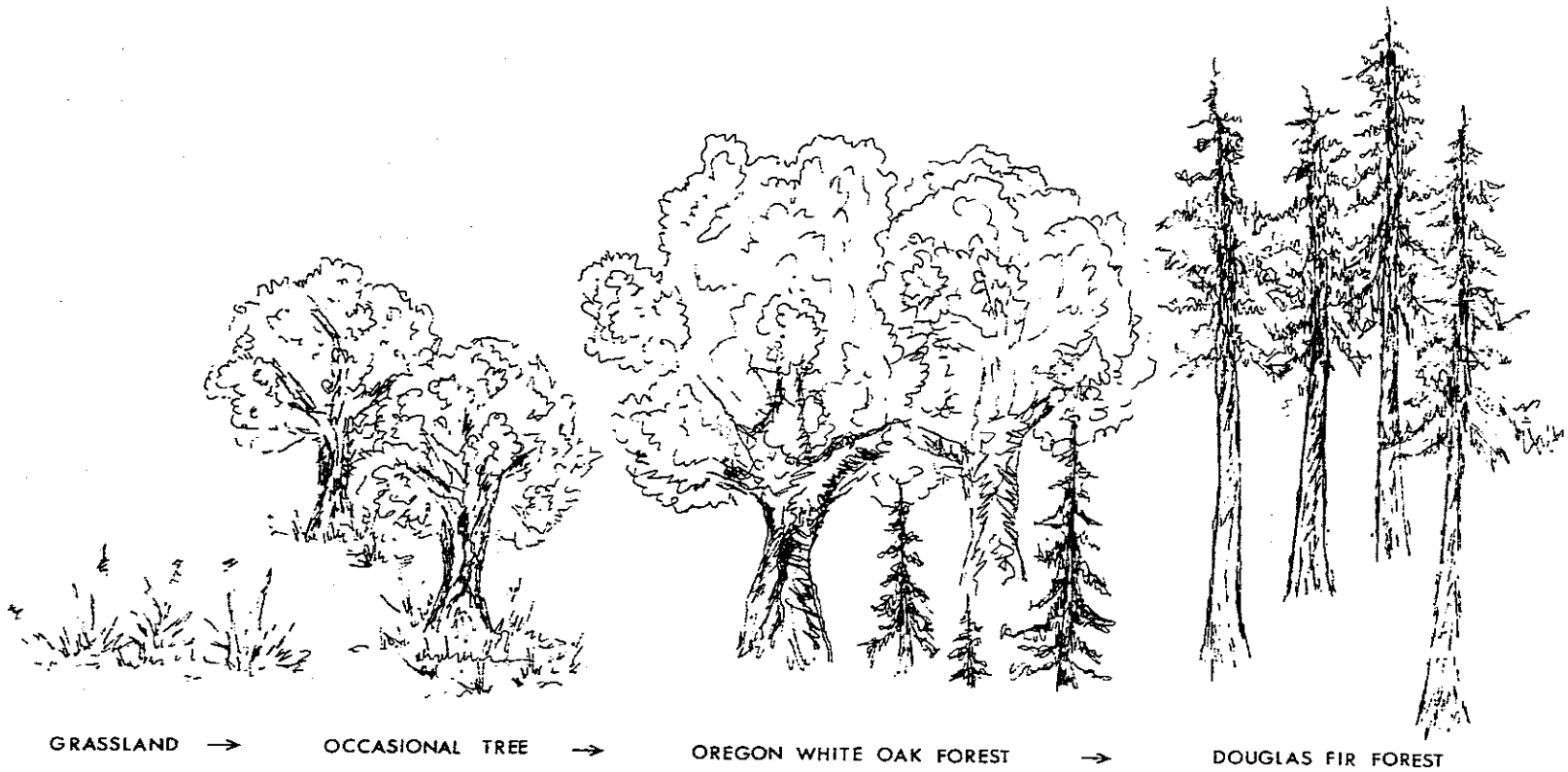

Figure 2.—Plant succession in western Willamette Valley at base of the Coast Range, Oregon.

TABLE 2.--Twelve most common breeding bird species of Oregon white oak.

Black-capped Chickadee
Bushtit
White-breasted Nuthatch
Brown Creeper
American Robin
Orange-crowned Warbler
MacGillivray's Warbler
Wilson's Warbler
Rufous-sided Towhee
Oregon Junco
Chipping Sparrow
Golden-crowned Sparrow

TABLE 3.--Twelve most common breeding bird species of Douglas-fir (Oregon).

Hairy Woodpecker
Steller's Jay
Chestnut-backed Chickadee
Red-breasted Nuthatch
Brown Creeper
Winter Wren
Hermit Warbler
MacGillivray's Warbler
Wilson's Warbler
Western Tanager
Rufous-sided Towhee
Oregon Junco

COMMUNITY ORGANIZATION

Studies of energy flow, biomass levels, and species interaction can be undertaken at the community level. Actual management of a community is often difficult because most of the data on avian habitat needs are available on the species level. By combining all habitat species information, it is possible to view bird species in relation to one another and to selected environmental characteristics.

Principal component analysis is one technique used for viewing information simultaneously for all species (Seal 1964). Thus, for example, Anderson and Shugart (1974) reduced the information contained in 28 correlated habitat variables (dimensions) to 3 uncorrelated principal components. By positioning each species within the 3-dimensional space, it was possible to show how each bird species related to the mean habitat vector or mean available habitat. Management implications could be drawn from understanding how habitat disturbances would shift the mean habitat vector relative to the positions of particular species in this space.

Smith (1977) demonstrated that habitat variables could be combined into principal components and bird species ordinated along each axis. Combining the results of discriminant and principal component analyses, he suggested that moisture gradients and tree size could be used to separate avian habitat niches.

Factor analysis is a statistical technique that can be used to reduce several habitat variables in a multidimensional space. It is similar to principal component

analysis; however, in factor analysis factors are scaled so that coefficients are the correlation coefficients with the original measurements. Factors can then be rotated to make them more interpretable biologically (see Overall and Klett 1972).

With this tool it is possible to reduce habitat variables to different factors and determine gradients of habitat or behavior attributes that influence avian communities. Anderson (1979) showed how three factors could be used to separate burned and unburned plots in a northern Michigan forest. The first factor represented forest maturity; the second, effect of burn; and the third, shrub cover.

Holmes et al. (1979) used factor analysis to examine similarities and differences of foraging patterns of birds in a New Hampshire forest. Key factors were foraging height, foraging location within the canopy, and differential use of tree species and foraging substrate.

Both principal component analysis and factor analysis assist in identifying key habitat components necessary for the existence of the bird community. These data need to be compiled and refined for each avian stratum to allow managers to use community attributes for managing nongame birds.

MANAGEMENT FACTORS

A number of specific attributes exist that managers can use to maintain nongame bird communities. These factors include total size of habitat, structure of habitat, streams or water impoundments, and the maintenance of edge.

One of the most important components in maintaining breeding bird communities is extent of contiguous habitat. Most data on this subject have been assimilated from forest bird community studies (Robbins 1979). In six study sites around Maryland, Robbins' data from up to 30 years show a major decline in species of long distance migrants (Table 4). The permanent residents, on the other hand, tend to maintain their population despite suburban sprawl and forest fragmentation. The short distance migrants that have adapted to survival in edge habitat, such as jays, House Wrens, catbirds, robins, Starlings, blackbirds, and towhees, also preserve their populations. To maintain communities of breeding birds, Robbins recommended that forests be managed in such a way that large tracts of contiguous canopy (2,500 acres and more) be intact at all times. He suggested that forest management plans be coordinated to retain such tracts of woods.

TABLE 4.--Populations of some bird species that have declined in the Maryland--Washington, DC region (1947-1978) (Robbins 1979).

Yellow-billed Cuckoo
Ruby-throated Hummingbird
Eastern Wood Pewee
Yellow-throated Vireo
Black-and-white Warbler
Worm-eating Warbler
Northern Parula Warbler
Ovenbird
Louisiana Waterthrush
Kentucky Warbler
Hooded Warbler
American Redstart

Most of the habitat variables correlated with bird species are components of habitat structure. Foliage height profiles can be correlated with bird species diversity (MacArthur and MacArthur 1961). Such data indicate that the structural aspect of the habitat is an important feature that can be used for managing nongame birds. When biologists examine different successional seres they are actually talking about changes in structure that influence the bird community. Community structure can be altered by logging, fire, and human development. This means that some form of predictive equation can be developed to show how this form of structural alteration, which is in effect an abrupt change of the community to a different successional sere, can be used to predict avian changes. Such predictions need to be developed for each community type which falls within the stratified zones listed earlier in this paper.

Water is another component of the community that can be used to attract some nongame birds. Although impoundments have been used to attract migrating waterfowl and provide areas in marshes for nesting birds, many nongame birds can also be maintained by streams, small ponds, lakes, and marshes. In this situation it is necessary to determine the types of populations that can be associated with each size and type of aquatic habitat. In some situations riparian forests develop along waterways. Their structural differences, as well as proximity to the food or water and insects attracted to this area, provide opportunities for different bird communities to survive. In the Jackson Hole area of Wyoming and other places in the mountain states, dense groves of aspen develop in the riparian habitat due to available water. Although aspens are also found on mountainsides and valleys, the aspen forests along the riparian habitat have a unique structure and provide ideal communities for breeding cavity-nesting species. The distinction that exists between these riparian habitats in the Jackson Hole area and surrounding forests can be easily seen in Tables 5, 6, and 7.

TABLE 5.--Twelve common bird species of riparian aspen community--Jackson Hole, Wyoming.

Red-shafted Flicker
Hairy Woodpecker
Downy Woodpecker
Western Wood Pewee
Tree Swallow
Black-capped Chickadee
Mountain Bluebird
Warbling Vireo
Yellow Warbler
Black-headed Grosbeak
White-crowned Sparrow
Lincoln's Sparrow

TABLE 6.--Common bird species of lodgepole pine community.

Red-shafted Flicker
Downy Woodpecker
Gray Jay
Mountain Chickadee
Hermit Thrush
Audubon's Warbler
Oregon Junco
Chipping Sparrow

TABLE 7.--Twelve common bird species of spruce forest community.

Hairy Woodpecker
Clark's Nutcracker
Mountain Chickadee
Red-breasted Nuthatch
Brown Creeper
American Robin
Townsend's Solitaire
Ruby-crowned Kinglet
Cassin's Finch
Pine Grosbeak
Pine Siskin
Oregon Junco

Another feature useful in maintaining nongame bird communities is edge (Lay 1938). Edge is especially important to bird populations, as has been shown in studies listing a greater number of bird species in areas of mixed habitat found at the edge of two plant communities (Johnston 1947).

Gates and Gysel (1978) indicated in a study of fledgling success in forest openings that each bird species seems to have a preferred distance from the habitat discontinuity or the edge. They found that over half of the nests were within 15 m of the edge, at which a large number belonged to birds characteristic of mixed breeding habitat.

Whereas edge is a concept for managers to recognize and use, it can be overemphasized. Thus, when looking at the positive effects of transmission-line corridors, some individuals speak of the increased edge. This information must be taken into context of the total community size. Many birds characteristic of forest interior habitats are unable to maintain their populations in the vicinity of edge habitats (Robbins 1979). If a transmission-line corridor, roadway, or other opening in a forest results in decreasing that forest's area to a size below which the normal community can survive, then it may have an adverse impact.

MANAGEMENT IMPLICATIONS

Managers have a variety of information currently available to consider in maintaining nongame bird communities. Many additional questions, however, remain to be answered. Although I have spoken of the total extent of habitat, I can point out that to maintain most nongame communities it is important to keep not only a mature plant community but also a variety of successional serres. Some forms of controlled human disturbance can therefore be an important component of management, if they tend to create a diversity of habitat types of sufficient size.

Nongame bird communities can be managed as a secondary objective on a tract of land. When features associated with bird communities are known, foresters, range managers, and wildlife managers can use this information to maintain bird communities on land where specific goals are clearly defined. Thus, foresters can utilize timber practices to coincide with the total size of forest necessary to maintain bird communities. Occasional snags can be left standing for cavity nesters. Care should be used in considering this option, however, because as Robbins (1979) points out, excessive retention of snags can create an adverse impact due to disease and perch sites for cowbirds.

Overall, wildlife managers need to clearly state the objectives they are seeking and then utilize sound habitat information to manage the nongame bird community.

Biologists need to define basic units of habitat and prescribe major features of the environment necessary to maintain nongame communities for each ecoregion and successional stage.

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APPENDIX I

Common Name	Scientific Name
Yellow-billed Cuckoo	*Coccyzus americanus*
Ruby-throated Hummingbird	*Archilochus colubris*
Red-shafted Flicker	*Colaptes auratus*
Hairy Woodpecker	*Picoides villosus*
Downy Woodpecker	*Picoides pubescens*
Eastern Wood Pewee	*Contopus virens*
Western Wood Pewee	*Contopus sordidulus*
Tree Swallow	*Iridoprocne bicolor*
Gray Jay	*Perisoreus canadensis*
Steller's Jay	*Cyanocitta stelleri*
Clark's Nutcracker	*Nucifraga columbiana*
Black-capped Chickadee	*Parus atricapillus*
Mountain Chickadee	*Parus gambeli*
Chestnut-backed Chickadee	*Parus rufescens*
Bushtit	*Psaltriparus minimus*
White-breasted Nuthatch	*Sitta carolinensis*
Red-breasted Nuthatch	*Sitta canadensis*
Brown Creeper	*Certhia familiaris*
House Wren	*Troglodytes aedon*
Winter Wren	*Troglodytes troglodytes*
Bewick's Wren	*Thryomanes bewickii*
American Robin	*Turdus migratorius*
Wood Thrush	*Hylocichla mustelina*
Hermit Thrush	*Catharus guttatus*
Veery	*Catharus fuscescens*
Mountain Bluebird	*Sialia currucoides*
Townsend's Solitaire	*Myadestes townsendi*
Ruby-crowned Kinglet	*Regulus calendula*
Starling	*Sturnus vulgaris*
Yellow-throated Vireo	*Vireo flavifrons*
Warbling Vireo	*Vireo gilvus*
Black-and-white Warbler	*Mniotilta varia*
Worm-eating Warbler	*Helmitheros vermivorus*
Orange-crowned Warbler	*Vermivora celata*
Northern Parula Warbler	*Parula americana*
Yellow Warbler	*Dendroica petechia*
Audubon's Warbler	*Dendroica coronata*
Hermit Warbler	*Dendroica occidentalis*
Ovenbird	*Seiurus aurocapillus*
Louisiana Waterthrush	*Seiurus motacilla*
Kentucky Warbler	*Oporornis formosus*
MacGillivray's Warbler	*Oporornis tolmiei*
Hooded Warbler	*Wilsonia citrina*
Wilson's Warbler	*Wilsonia pusilla*
American Redstart	*Setophaga ruticilla*
Western Tanager	*Piranga ludoviciana*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Cassin's Finch	*Carpodacus cassinii*
Pine Grosbeak	*Pinicola enucleator*
Pine Siskin	*Carduelis pinus*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Oregon Junco	*Junco hyemalis*
Chipping Sparrow	*Spizella passerina*
White-crowned Sparrow	*Zonotrichia leucophrys*
Golden-crowned Sparrow	*Zonotrichia atricapilla*
Lincoln's Sparrow	*Melospiza lincolnii*

WESTERN FOREST TYPES AND AVIAN MANAGEMENT PRACTICES

Frederick C. Hall

Regional Ecologist
USDA Forest Service
Pacific Northwest Region
Portland, Oregon

ABSTRACT

The species composition, structure, and distributional pattern of forest vegetation directly influences wildlife species, their density, and distribution. Pristine vegetation is discussed as a baseline for evaluating management practices. Inherent vegetation composition, structure and pattern is caused by soil and topographic characteristics and differences in climate, for example, the natural pattern of different habitat types. Induced vegetation pattern is caused by disturbances such as lightning fires. Thus, induced structure is dynamic; it changes as plant succession moves from grass-forb to poles, sawtimber and old growth. Induced pattern is dynamic, changing geographically as different areas are disturbed. Wildlife species, population density, and distribution are also dynamic. Forest managers must accept that we cannot return forests to pristine conditions, that timber management will be practiced on most forest lands, that vegetation will change, and that inherent vegetation patterns will influence the selection of treatment to enhance wildlife. Wildlife habitat can be enhanced by modifying silvicultural treatment, modifying scheduling of treatment, and by allocating land areas to emphasize wildlife management objectives.

KEYWORDS: Climax, pristine, succession, climate, land, wildlife habitat, storms, vegetation pattern, inherent edge, induced edge, crownfire, underburn, stand structure, silviculture, rotation age.

INTRODUCTION

Wildlife responds to vegetation structure, species composition, and pattern of vegetation (Thomas, et al. 1979c). Structure refers to the size, diameter, age, health, and different layers in the overstory and/or understory of a forest stand. Species composition deals with species dominance in the various layers. Structure and composition are separate forest stand characteristics. For example, old-growth structure can be composed of ponderosa pine or grand fir or lodgepole pine or western juniper. Pattern of vegetation is the juxtaposition of different stands such as old-growth forest adjacent to natural grassland (Fig. 1) and size of the stand. Thus, a one acre natural grassland opening in a forest will affect wildlife differently from a 500 acre grassland opening.

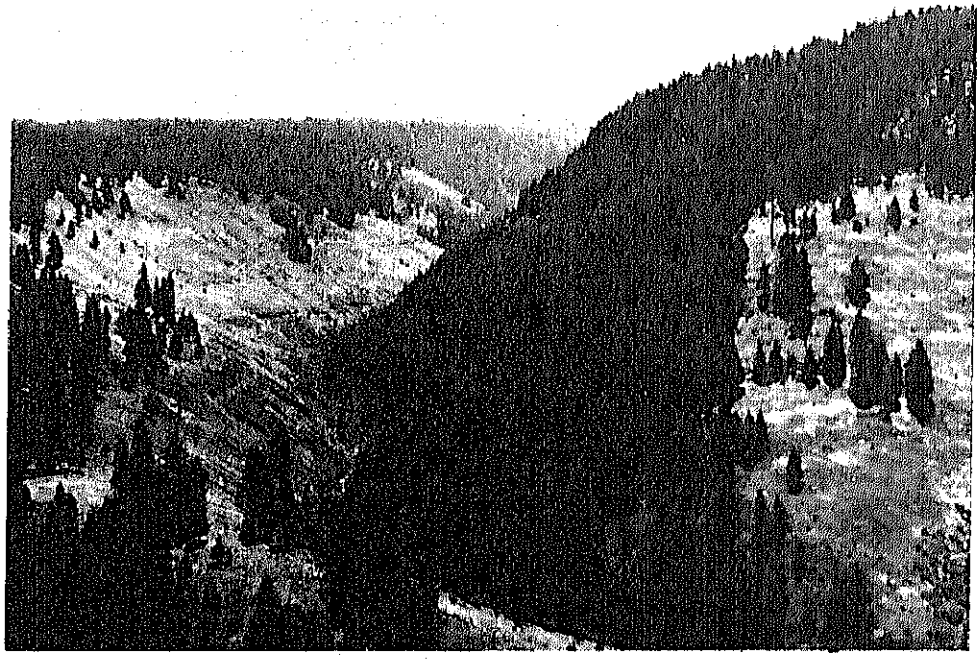

Figure 1. Inherent vegetation pattern caused by differences in soil and topography. North slope (right) is grand fir, south slope (left) shallow soil bunch grass and gentle ridge (far right) is bunchgrass scabland.

Vegetation

Vegetation, which is wildlife habitat, is a function of land and climate. Land includes both soil and topography. Climate has two aspects: average temperature and precipitation characteristics, and nature of storms. The concept of site potential vegetation (habitat type) is based on average climatic temperature and precipitation coupled with soil and topography (Daubenmire 1952).

In the West, for example, as precipitation changes from eight inches to 28 inches vegetation changes from grassland or sagebrush (Artemisia spp.) to ponderosa pine (Pinus ponderosa Dougl.) to fir (Pseudotsuga spp. Abies spp.). Within a climatic zone different kinds of vegetation occur due to topographic and soil influences. For example, within the ponderosa pine zone, shallow soils may produce grassland and steep north slopes may foster Douglas-fir [Pseudotsuga menziesii (Mirbel) Franco] (Fig. 1).

Climate

Storms are probably the greatest climatic factor influencing not only vegetation, but also soil and land. For example, some areas of the West have dry lightning storms which start fires. In other areas, heavy thunderstorm precipitation occurs; as much as three inches of rain can fall in 20 minutes in a 25 year storm. These conditions tend to cause catastrophic geological erosion. Wind storms can also alter forest vegetation.

The most common and widespread storm disturbance factor appears as lightning which starts fires. These fires can be broken into two kinds: crown fires occurring infrequently, for example, at 150- to 500-year intervals, and low intensity fires

burning frequently--at five to 20 year intervals. The latter are commonly referred to as underburns in a forest stand. Crown fire has been commonly associated with such pioneer forest species as lodgepole pine (Pinus contorta Dougl.), western white pine (P. monticola Dougl.), western larch (Larix occidentalis Nutt.), quaking aspen (Populus tremuloides Michx.), and in the Pacific Coast states, Douglas-fir (Weaver 1974). Low intensity fires or underburning, have been most closely associated with ponderosa pine, maintenance of Great Plains oak savanna, and maintenance of grassland in a sagebrush or juniper/sagebrush climatic climax (Vogl 1974, Humphery 1974).

PRISTINE

Pristine vegetation is discussed in regard to a space system and a time system. Pattern of vegetation is the spatial location of different kinds of vegetation. Time deals with how long a forest stand will remain in a successional stage or in a certain stand structure.

Space System

Vegetation pattern is expressed in two ways. Soil and topography create an inherent pattern in different kinds of potential vegetation or habitat types (Daubenmire 1952). Storms create an induced pattern by causing disturbances, such as fire, which produce successional stages within a kind of potential vegetation.

INHERENT PATTERN

Inherent pattern is shown in Figure 1. Shallow soil produces natural bunchgrass (Sporobolus airoides Torr.) openings. Northerly aspects produce Douglas-fir and grand fir [Abies grandis (Dougl.)Lindl.] forest. Between these two is an inherent edge used by wildlife (Thomas et al. 1979b). Thus, there is a natural diversity in the species composition and structure of vegetation and the size of tract that will produce a given kind of vegetation.

Wildlife takes advantage of the different species composition and structure of vegetation. Some species reproduce and feed primarily in openings; others in old-growth forest, and still others are adapted to the edge between forest and nonforest. Thus, inherent pattern can also be a limitation. Natural openings may be much larger than optimum for some wildlife. Or they may occupy more land area, such as 50 percent, than would be optimum habitat diversity. Should a forest be disturbed in a setting with 50 percent in natural openings, wildlife habitat diversity could be further reduced if succession was taken back to the grass-forb stage (Hall and Thomas 1979).

INDUCED PATTERN

Induced pattern is a mosaic of successional stages caused by disturbances primarily associated with storms (Thomas et al. 1979b). A crown fire could burn a 400-acre tract in a stand of grand fir creating a dramatic edge between mature fir and grass-forb or shrub-seedling vegetation as shown in Figure 2. As the time progresses, lodgepole pine could seed into the burn creating a different composition and structure of vegetation, initially lodgepole saplings adjacent to mature fir, then a pole stand adjacent to mature, and finally mature lodgepole adjacent to mature fir.

Figure 2. Induced vegetation pattern caused by crown fire in mature grand fir. Four stand ages can be seen: old-growth grand fir, mature grand fir with some decadent lodgepole pine, 100 year old lodgepole pine, and a recent burn now dominated by shrubs.

Induced vegetational pattern is highly dynamic. A natural grassland opening may exist for 10,000 years; a small fire induced opening for only 20 years. Thus, some wildlife species taking advantage of an induced opening or edge will be displaced within a certain period of time and replaced by different species better adapted to the new and changing habitat.

TRACT SIZE

Most wildlife species, during the breeding season, defend a reasonably well defined territory (Thomas et al. 1979c). Thus, a tract half the size of a territory probably will not be occupied by that species whereas a tract five times larger than a species' territory might be occupied by up to five pairs of those species. Under pristine conditions, tract size had no relation to wildlife habitat needs. There is no choice in inherent vegetation. Induced pattern was a function of stand condition and storm-produced disturbance. The disturbance could be large, such as 250,000 acres during the Wenatchee fires of 1970, or simply a spot burn where a single tree was killed. Thus, pristine conditions do not necessarily produce optimum wildlife habitat.

Time System

All forest stands are dynamic. Stand structure changes over time. Storm disturbance tends to produce even-age stands. Crownfires result in new species composition and a very dramatic change in structure. In contrast, underburning tends to maintain successional vegetation and a reasonably similar stand structure.

CROWNFIRE

Crownfire has the most dramatic impact on induced vegetation patterns. Following burn, forest structure changes to open grass-forb then a few years later to a shrub-seedling stage. These are very similar in structure to natural grassland or shrub-grassland openings. In the Blue Mountains of eastern Oregon, for example, 40 percent

of the 378 vertebrates were primarily oriented in both reproduction and feeding to nonforest structure of vegetation (Thomas et al. 1979c).

The important factor between inherent openings and induced openings is time. A burn might change from the grass-forb and shrub-seedling stage to saplings in 20 to 50 years depending upon success of tree regeneration. Should the area be reburned, time in this stage may extend to 150 years.

Eventually these burns will change from saplings into pole, small, and medium sawlog structure. Stand diameter, age, health, and species are greatly influenced by initial stand density following a burn. For example, when excessive numbers of trees become established, the stand may stagnate at sapling or pole size rather than develop into sawtimber structure (Fig. 1). Stand stagnation throughout the West is extremely common. Thus, the amount of time in the pole and sawlog size may range from 50 to 200 years. In the Blue Mountains, only 10 to 20 percent of the vertebrates are oriented primarily to these kinds of stands (Thomas et al. 1979c).

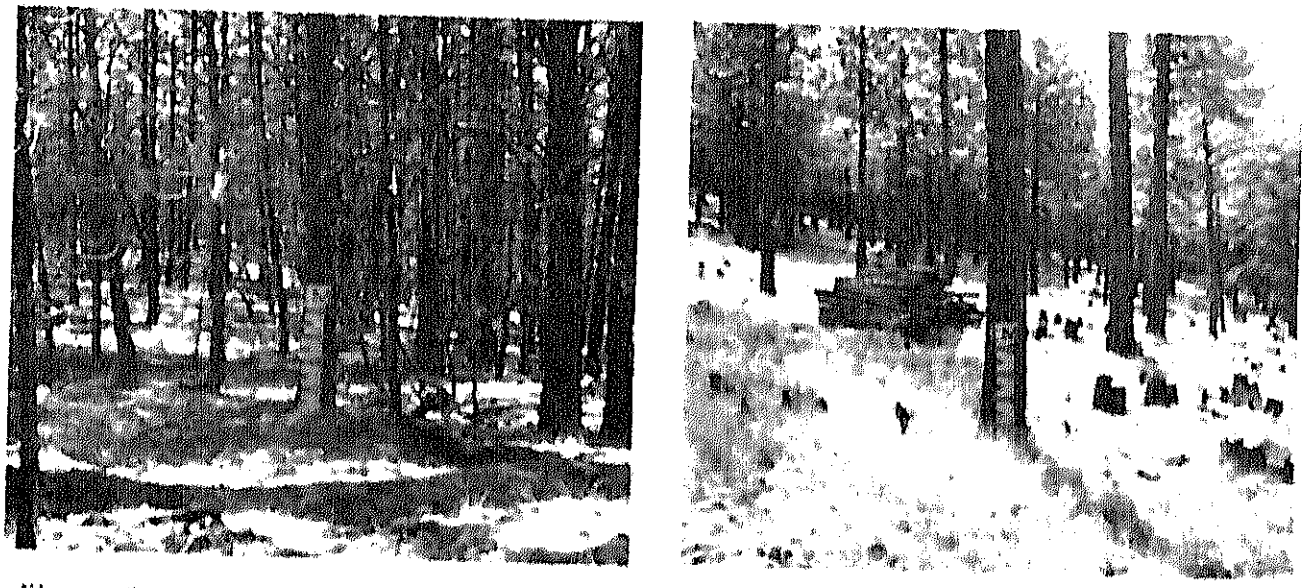

Figure 1. A ponderosa pine stand photographed in 1963 at age 60 (left) in stagnated condition and again in 1973 ten years after precommercial thinning. Wildlife habitat changed from dense sapling hiding cover to small pole open conditions. Natural underburning kept these stands thinned and prevented stagnation.

The stand should develop into old-growth structure given enough time. One common misconception is that old-growth is synonymous with climax. This is definitely not the case.

Many old-growth stands have a major overstory component of large diameter, tall, successional trees such as larch, white pine, ponderosa pine, or Douglas-fir in the Pacific Coast States. The understory is commonly dominated by climax species. Height and large diameter of dominant trees in old-growth is an important stand structural characteristic. In many cases, these trees developed from burns that were very lightly stocked--for example, 50 to 100 trees per acre by age 10. Trees grew rapidly in height and diameter because of low stand densities. Often, dominant successional species attained half their present diameter in the first 100 to 150 years.

Old growth was characteristically cycled by fire as dry fuels built up following death of the pioneer trees. This is a primary reason why few old-growth stands in the West have reached what might be considered climax.

In contrast to old growth, climax (without fire influence) would be dominated in the overstory and understory by shade tolerant species. Trees would tend to be of all ages and all effects of fire on stocking level control would be lost. Tree regeneration would have slow height and diameter growth, for example, 2 to 4 inches in height, and 30 to 80 rings per inch diameter growth. Retardation of height and diameter growth would produce a stand structure quite different from old growth. Instead of tall, large diameter trees such as 150 feet and 36 inches diameter for larch on a grand fir site, dominant trees might only be 80 feet tall and 10 inches in diameter because of long periods of suppression in the understory. In addition, tons of slowly decaying logs would cover the ground creating a tremendous dry fuel load susceptible to ignition by lightning.

Crownfire creates a very dynamic vegetation which then causes a similarly dynamic wildlife system as it responds to changing habitat. For example, a single burn can change stand structure from old growth to open grass or shrub nonforest, then proceed through successional stages to a simulation of old growth in only 150 years. Pristine old growth today is changing. Overstory dominant successional species such as ponderosa pine, larch, or white pine are dying leaving a dominance of climax species with smaller diameters and less stand height.

UNDERBURNING

Periodic light burns, at five to 20 year intervals, have been well documented in forest stands by fire scar evidence (Hall 1977, Weaver 1974). Documentation in western juniper (Juniperus occidentalis Hook.) and sagebrush/juniper potential sites has been more difficult because light underburning tends to prevent the establishment of woody species and creates a grassland type of vegetation. This in no way, however, diminishes the influence that periodic burning has had in juniper or sagebrush vegetation (Humphery 1974).

In forest stands, underburning has several important influences. It maintains ponderosa pine in a fir climax and at times it maintains western larch in a fir climax (Fig. 4). Fires also maintain stocking level control by periodically eliminating most regeneration. Thus, fires prevented stand stagnation so common today (Fig. 3). These burns also tended to maintain fire dependent vegetation such as ceanothus (Ceanothus spp.) and legumes, species which require heat treatment for seed germination (Hall 1977).

And finally, underburning tended to have an opposite effect from crownfire; it tended to prolong time in a particular vegetation composition and stand structure. For example, in the Pacific Northwest, it tended to maintain ponderosa pine/pinegrass (Calamagrostis rubescens Buckl.) in open stand conditions whereas dense grand fir and Douglas-fir are characteristic of a nonfire climax (Hall 1977).

Pristine stand conditions are actively changing today. Fire suppression has promoted stand stagnation and on many sites a dramatic shift in stand structure. Thus new wildlife niches are being created which were not common prior to fire suppression. For example, juniper is colonizing sagebrush sites, a dynamic change which can occur in 20 to 50 years. Thus, a shrub/grass stand structure with its related wildlife is changing to trees/shrub/grass which may have different wildlife. Fir has

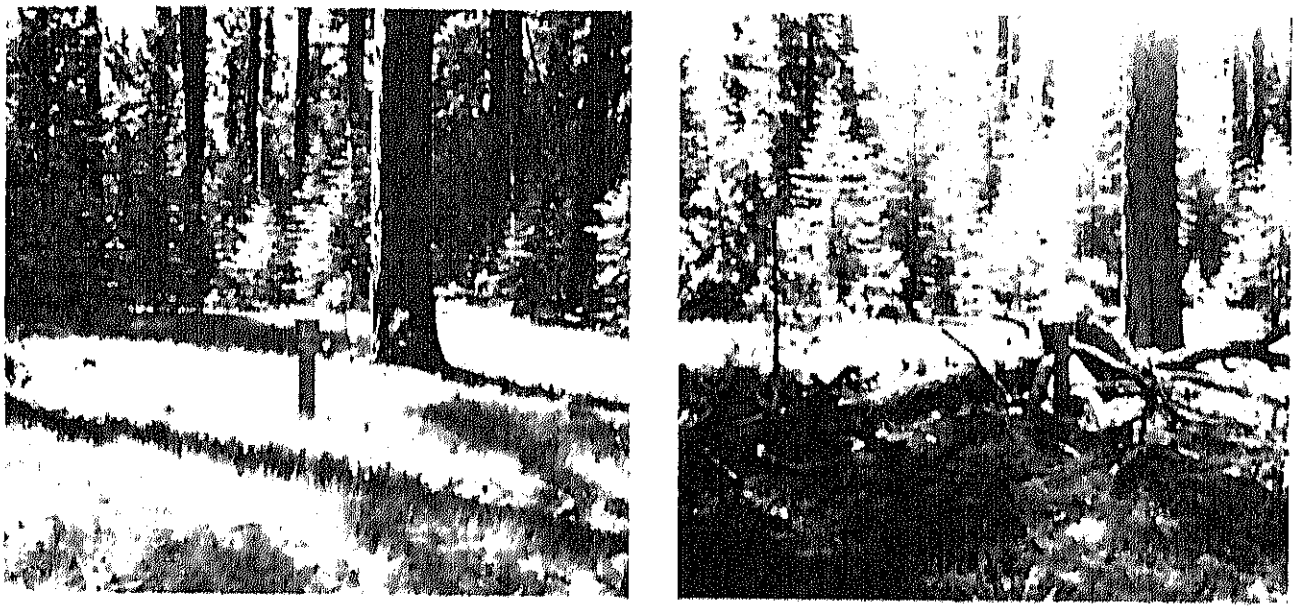

Figure 4. A ponderosa pine dominated stand photographed in 1964 (left) and in 1974. Grand fir and Douglas-fir have regenerated since fire suppression. As the pine dies (tree foreground), fir greatly increased in rate of height growth. This stand condition, pine with fir understory, is not pristine; instead it is man-caused resulting from fire suppression.

been demonstrated to volonize ponderosa pine stands only 20 to 30 years after fire suppression (Hall 1977). With no logging, old-growth pine may dramatically shift to a dominance of grand fir in only 150 years (Fig. 4). Stagnated stands can develop in only 20 years and stay that way for at least 60 years (Fig. 1). This might be highly desirable elk hiding cover but it does not enhance habitat for cavity excavators that require 12-inch diameter or larger trees.

Wildlife Systems

Wildlife responds to the dynamic changes in vegetation. Species and population densities change with succession following crownfire (Thomas et al. 1979c). Other wildlife species adapted to periodic underburning. Thus, the density, distribution, and kind of species are a function of inherent and induced structure and composition of vegetation. The kind of species seem to be influenced primarily by stand structure, density by size of tract, and diversity by inherent and induced vegetation pattern.

TODAY

We must accept an inherent pattern of natural site potentials. We do not have to accept as optimum the uncontrolled induced pattern of vegetation in its various tract sizes, locations, structures, and species composition. The pristine combination of induced and inherent vegetation pattern was not necessarily optimum for wildlife because it was not developed for wildlife.

Management Orientation

Pristine structure, pattern, and time and various successional stages is generally not desired in managed forests today. Dead or dying trees are salvaged thus eliminating snags from stand structure. We try to kill tussock moth and spruce bud-

worm--snag makers. Wildfires are suppressed, the pristine source of grass-forb and shrub-seedling stages, and a prerequisite to optimum old-growth structure.

Wood production is a primary consumptive use of forestland. To maximize wood production, elimination of old growth and shortening (or possibly eliminating) the grass-forb and shrub-seedling stages are emphasized. The objective is rapidly growing pole to sawtimber size stands which accommodate only about 20 percent of the wildlife species in the Blue Mountains of Eastern Oregon. About 40 percent are oriented to grass-forb and shrub-seedling stages for both feeding and reproduction, while the other 40 percent are oriented toward mature and old-growth stand conditions (Thomas et al. 1979c). In addition, forest monoculture seems advocated by planting a single tree species to produce the kind of product desired. Commercial thinning is planned to "capture mortality." Forest residue is reduced to aid fire control and to permit vehicle movement within the forest. In general, consumptive uses re-orient vegetation dynamics toward man's desired products.

Opportunities

Today, MAN controls induced pattern--whether by default with fire suppression or by intent with timber management. We must, therefore, accept several factors:

1. Forests will be harvested to produce a certain programmed cut.

2. Pristine conditions can not be regained because the smoke produced would violate the Clean Air Act.

3. Vegetation is changing, and will continue to change, thus wildlife will change in species, density, and distribution.

4. Inherent vegetation pattern will influence the effect stand treatment has on wildlife.

Considering these, there are three kinds of opportunities to enhance wildlife habitat: modify silvicultural treatment; modify treatment scheduling, location of areas, and size of tracts to be treated; and modify land allocation for management objectives whereby timber is de-emphasized and wildlife habitat is emphasized.

SILVICULTURAL TREATMENT

Stand structure is a primary factor modified by silvicultural treatments, for example, type of regeneration cut, stocking level control, and selecting type of trees to cut (Hall and Thomas 1979). The length of time in grass-forb and shrub-seedling stages can be increased with early and heavy precommercial thinning--or shortened and hiding cover enhanced by no precommercial thinning (Fig. 5). Stand diameter can be increased with commercial thinning from below. Snags can be retained by not prescribing salvage treatments, or can be created by girdling or topping.

Figure 5. A clearcut in grand fir planted to ponderosa pine photographed at 5 years in 1957 (left) and again 15 years later in 1972. In only 20 years, wildlife habitat changed from grass-forb to dense saplings.

SCHEDULING TREATMENT

Pattern or distribution of treated areas and size of tract treated are primary factors influencing wildlife habitat. For example, in extensive stands of old growth, wildlife habitat can be enhanced with regeneration cuts creating the grass-forb or shrub-seedling habitat and producing edges (Fig. 5). In the Blue Mountains of eastern Oregon, tract size of 40 to 80 acres is optimum for wildlife diversity. Edges should be less than 1,200 feet apart and retained uncut tracts should be more than 1,200 feet between regeneration areas (Thomas et al. 1979c).

Treatments must also be scheduled over time. For example, 20 percent of a land area in grass-forb and shrub-seedling structure might optimize wildlife habitat. Following clearcut or shelterwood regeneration, the desired nonforest structure could be maintained for 20 years by either planting trees at a wide spacing or by early and heavy precommercial thinning (Fig. 5). A 100-year timber rotation would be required to maintain 20 percent of the land in grass-forb and shrub-seedling successional stages. Regeneration treatment would have to be scheduled about every 20 years on one-fifth of the area. Old-growth structure could not be attained (Hall and Thomas 1979).

The land manager must also consider inherent pattern of vegetation. For example, a land area only 60 percent forested already has the "grass-forb" and "shrub-seedling" stages in abundance (Fig. 1). In this case, clearcut regeneration may wildlife. It would only increase the percentage of area in nonforest (Thomas et al. 1979a).

LAND ALLOCATION

Maximum production of timber products
land area in grass-forb and shrub-seedling s

reduction in potential yield. The reduction is caused by slower growth, heart rot development, and production of snags and downed material important as wildlife habitat (Wick and Canutt 1979, Maser et al. 1979). Thus, wildlife habitat enhancement will require allocation of land to old growth structure and function.

Allocation to old growth requires a different rotation age than maximum timber management, for example, 300 instead of 100 years. This does not preclude silvicultural treatment to attain old growth. To the contrary, stocking level control is required to produce large diameter, tall, successional trees often important as old-growth wildlife habitat (Hall and Thomas 1979). For wildlife species such as pileated woodpecker which use successional pine and larch in a fir climax in eastern Oregon, stand age exceeding 300 years may no longer be suitable habitat because pine or larch would have died out. In this case, the stand should be regenerated to pine or larch and treated over a 300 year rotation to again attain old-growth structure.

Land allocation to wildlife habitat should consider three factors: what kinds of forest types should be considered; how much of the total land area should be devoted to old growth and nonforest structure; and what kind of geographic distribution is desired. These allocations are probably best developed by an interdisciplinary team approach to land management planning.

SUMMARY

Pristine conditions are characterized by a dynamically successional vegetation and by vegetation pattern. Vegetation is a function of land (soil and topography), and climate (temperature, precipitation, and storms). Pattern is both inherent due to site potential and induced due to disturbance. Both inherent and induced patterns produce dramatic differences in structure, species composition, and distribution of vegetation.

Wildlife generally is a function of habitat which is composition, structure, and pattern of vegetation. Thus, the species, diversity, and density of wildlife change as the vegetation changes. It is a total, dynamic, interactive system.

In order to evaluate management for wildlife, we must accept that a certain timber volume will be cut. We cannot go back to pristine conditions; vegetation will change, thus wildlife will change, and inherent patterns will cause a certain kind of stand treatment to affect wildlife differently. We have basically three opportunities to enhance wildlife: modify silviculture treatment, modify scheduling of treatment, and modify land allocation for wildlife tradeoffs.

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GRASSLAND MANAGEMENT PRACTICES AND BIRD COMMUNITIES

Walter D. Graul

Nongame Research Leader
Colorado Division of Wildlife
317 W. Prospect
Ft. Collins, CO 80526

ABSTRACT

Public grasslands must play a major role in the preservation and enhancement of avian communities because, as compared to other broad habitat types, a disturbingly high percentage of native grassland in the U.S. already has been destroyed or badly abused, and there is relatively little public grassland available for management. The general features of avian grassland communities that form a foundation for management are: (1) low species diversity, (2) numerical dominance by 1 or 2 widespread, eurytopic species, and (3) the presence of a few stenotopic species. A management approach is proposed that is designed to maintain all existing functional elements of a grassland avian community. Other management aspects addressed include habitat conversion practices, water management, grazing, size of land holdings, timing of human activities, and the use of artificial structures in avian management.

KEYWORDS: bird management, grassland, Great Plains, ecosystem management.

INTRODUCTION

The biological value and potential of public grasslands are receiving considerable attention recently on a national scale. The National Audubon Society has been examining the National Grassland system and their results should be forthcoming. Efforts to establish new National Grasslands are in progress (HB5592 in the U.S. Congress, 1980). Articles on the value of grasslands are reaching many segments of the general public (Brandenburg 1980; Nature Conservancy 1977).

This widespread interest in public grasslands is certainly justified. One reason for this is that many grassland ecosystems have been destroyed or severely abused on a scale that does not apply to most major ecosystems in the United States. The destruction of grasslands has been documented by Klopatek et al. (1979). They estimated that on the Great Plains the percentages of selected Küchler prairie types

already destroyed are as follows: bluestem prairie-85%; bluestem-grama-65%; grama-buffalo grass-45%; and Nebraska sandhills prairie-6%. For comparison, the parallel values from the same publication for some selected western forest types are as follows: juniper-pinyon forest-1%, Black Hills pine forest-5%, and western ponderosa pine-3%.

The biological value of public grasslands is even more important since there are only about 4 million acres of U.S. National Grassland; as compared to 182 million acres of National Forest (USDA Forest Service 1964). Furthermore, most of these 4 million acres were severely abused prior to incorporation into the National Grassland system. In fact, these grasslands were acquired because of their poor condition; purchased from bankrupt landowners. Unfortunately, there are no public, or private, grasslands that represent pristine ecosystems; many characteristic species are already gone. The current challenge is to preserve what remains. This is the intent of this paper with respect to one major grassland community element--birds.

The Great Plains contain 17 of the 19 National Grasslands managed by the U.S. Forest Service (USDA Forest Service 1964). Furthermore, the Great Plains hosts over 50% of the breeding bird species found in the lower 48 states, although it comprises less than one fifth of this area (Johnsgard 1979). Most of this species richness, however, is tied to the wetlands and timbered riparian areas addressed elsewhere in this workshop. I will dwell, therefore, upon management of actual grassland tracts, primarily of the Great Plains, although some statements will have broader applicability.

GRASSLAND AVIAN COMMUNITY STRUCTURE

Any consideration of management of bird communities must be based upon an understanding of the appropriate community characteristics. In this section, therefore, the key characteristics of Great Plains bird communities will be described.

The grasslands per se contain relatively few bird species. For instance, the mean number of breeding species of nongame birds reported on 98 study plots throughout the major segments of the Great Plains have been reported as follows: tallgrass prairie-4.1, mixed grass-4.7, and shortgrass prairie-4.3 (Wiens and Dyer 1975). In contrast, 106 breeding species of birds have been recorded in Wisconsin's mixed forest zone (Temple et al. 1979). For pure coniferous forests Wiens (1975) found the mean number of avian breeding species to be 2-4 times those reported in grasslands.

Although there is no doubt that grasslands contain a relative paucity of avian species, the situation is somewhat more complex than indicated by the above values. The problem is that there are many subtypes within categories such as shortgrass and tallgrass prairie. These subtypes occur in a mosaic pattern and different bird species are restricted to different subtypes. Consequently, the breeding species numbers are extremely low on a study plot basis, but a general habitat category can contain considerably more species. For instance, I have recorded nesting on the shortgrass prairie (excluding riparian and timbered zones) of the Pawnee National Grassland (north central Colorado) by 19 species of birds, and my list is certainly not exhaustive.

Another characteristic of grassland bird communities is that they tend to be dominated numerically by 1 or 2 abundant, widespread species. For instance, Wiens and Dyer (1975) found that, on average, about one-half of the avian individuals on any rangeland study plot belonged to one species, while 75% to 88% of the individuals were included in the 2 most abundant species.

The final important avifauna characteristic is that all of the broad grassland types contain species with extremely restricted habitat characteristics. However,

there are not many of these species. For instance, Udvardy (1958) reported that only 5.3% of all North American birds are truly grassland species. Johnsgard (1979) listed 36 species that have a breeding distribution generally associated with grasslands, and only 15 of these are endemic to the Great Plains.

MANAGEMENT CONSIDERATIONS

Statement of Goal

Any management program must be based upon a definite goal. Historically, wildlife management has been based upon single-species goals. This is the classical game management approach and it has been applied to nongame management in reference to threatened and endangered species programs (Anderson 1979). This single-species approach, however, is slowly being replaced, or at least supplemented, by considerations at higher levels of ecological organization. In short, we need to raise our thinking and actions to the ecosystem level (Odum 1977; Wagner 1977).

Following the preceding suggestion, I will address all of my management considerations towards the following goal: Maintain all general grassland types so that no existing avian species is lost as a functional element of its respective ecosystem.

General Management Approach

A risk of not meeting the above goal is inherent in any management approach that is not based directly upon the requirements of all species in a particular ecosystem. Unfortunately, many of these requirements are not known today (Graul et al. 1976). The risk factor, however, may be greatly reduced by addressing those species with known restricted habitat requirements (stenotopic species). In fact, such species should be intentionally maintained and enhanced where possible. By addressing the needs of these stenotopic species, the needs of many of the species with wide ranges of ecological tolerances (eurytopic species) will be met. Obviously, the reciprocal statement is not always true.

This stenotopic species approach is especially applicable to grassland avian communities, i.e. characterized by a few stenotopic species with dominance by 1 or 2 eurytopic species. To apply the approach, however, several steps must be followed. First, a list of all the avian species present on an area must be compiled. Secondly, species that are extremely peripheral historically (only occurred sporadically or in very low numbers), or accidental should be identified and removed from consideration, i.e. they probably should not be considered as functional elements of the ecosystem. Next, the stenotopic species must be selected from those remaining. Clues for the identification of these species are: (1) a relatively restricted distribution during one or more phases of the annual cycle, or (2) a patchy distribution throughout an overall broad range, or (3) substantial population declines where the declines may be attributed to habitat changes.

the separate stenotopic species. An example from the shortgrass prairie characteristic of the Pawnee National Grassland will illustrate.

The Mountain Plover (Charadrius montanus) prefers expansive flats covered by almost pure stands of blue grama grass (Bouteloua gracilis) and/or buffalo grass (Buchloe dactyloides) (Graul and Webster 1976). The McCown's Longspur (Calcarius mccownii) also does well on these areas, but seems to prefer areas where low to moderate densities of midgrasses, such as western wheatgrass (Agropyron smithii) are mixed with the shortgrasses. The Lark Bunting (Calamospiza melanocorys) thrives in areas where midgrasses are predominant. To accomodate all of these breeding species their respective habitat types must be maintained in a series of habitat units. Determining the exact size of the units relative to each other is a difficult decision. Although there are no precise answers in this regard, a general guideline is that all units should be large enough to sustain substantial numbers of the respective species. Additionally, one species might receive some preference if its population is at a more critical level than the other stenotopic species.

Building upon the management plan foundation, the next step is to incorporate the known requirements of other avian species that are functional elements in the ecosystem. In no case, however, should the requirements of a more eurytopic species override those of the stenotopic species, whether for ecological, political, or economic considerations.

Although the preceding approach is similar to other proposed approaches, the ecological differences are critical. The key to the approach described herein is that it is based upon a stenotopic species foundation. This is not necessarily the case with other management schemes. For instance, the "featured species approach" (Gould 1977) could be detrimental to some stenotopic species if the featured species involved turned out to be a eurytopic species. This is sometimes the case when the featured species are chosen for economic reasons. Even approaches aimed at management for diversity (Siderits and Radtke 1977) could potentially eliminate certain stenotopic species (Back 1979). For instance, maximum diversity could be obtained by providing a matrix of many small habitat types, but this could be extremely detrimental to a native, stenotopic species that requires a large block of uniform habitat. Of course, the preceding management approaches could have applications if the goal is not to maintain all of the avian species as functional elements of the ecosystem, i.e. the approach must be based on a carefully defined goal.

Special Management Considerations

The general management approach presented herein can be the foundation of any grassland management program, but other considerations can be added. Six considerations will be addressed in this section; they were selected because they represent active programs on the National Grasslands.

TYPE CONVERSIONS

Through a review of the various management documents of the National Grasslands I found that many acres historically were seeded with exotic species such as crested wheatgrass (Agropyron cristatum and A. desertorum). Most of these seedings were initiated to stabilize the soil following the Dust Bowl of the 1930's. Future seedings of this type should be viewed cautiously, since they are generally detrimental to native avian communities. In fact, both species diversity and relative density for vertebrates in general can be negatively impacted by crested wheatgrass plantings (Reynolds and Trost 1979). Studies by Hickey and Mikol (1979) illustrate the negative impacts of such seedings upon birds.

Seedings of crested wheatgrass and other exotic species may continue to be proposed for restoration of disturbed sites. Whereas this may be the only option on large-scale operations, the best solution on a small-scale may be to not seed (if native species cannot be seeded). For instance, blue grama grass rarely reproduces by seeds (Briske and Wilson 1978), but if small blue grama areas are disturbed they will be re-vegetated naturally via tillering. On a small scale, therefore, the temporary presence of bare ground and weeds may be less detrimental to stenotopic species than the long-term presence of exotic grasses. The latter statement may be especially applicable to disturbances caused by vehicle traffic, mineral exploration, and gas and oil pipelines. Obviously, existing laws frequently require restoration by seeding, but I feel that some of these laws should be re-evaluated.

Another major type conversion practice that has been applied on National Grasslands to foster cattle production is "pitting." This involves using a machine to dig a series of shallow trenches on shortgrass prairie expanses. The trenches capture moisture and presumably promote the presence of midgrasses such as western wheatgrass. If this practice is considered, it should be recognized that it potentially can have a negative impact upon stenotopic species that prefer pure expanses of shortgrass, e.g. the Mountain Plover. Interestingly, at least on one National Grassland pitting is being applied as a potential control mechanism for prairie dogs (Cynomys ludovicianus). In such cases, the desired objective should be weighed carefully against the potential impacts upon other forms of wildlife; the impacts can be positive or negative, depending upon the species. Likewise, when pitting is considered for increasing livestock forage it should be within a multiple-use framework--wildlife objectives should be included.

Another widespread type conversion practice on the National Grasslands is planting trees. These plantings range from isolated trees to vast acreages such as the Bessey tract of the Nebraska National Forest. The latter tract in the sandhill grasslands constitutes the largest man-made forest in the world (17,518 acres).

In terms of the goal stated in this paper, tree plantings should be evaluated prudentially. The potential positive benefits must be weighed against the potential negative benefits on a case by case basis. For instance, a few scattered trees can have a positive influence on nesting raptor populations. If these trees, however, are placed adjacent to restricted waterholes, or grouse leks, the presence of the raptors can have a negative impact upon other aspects of the avian community. Additionally, any large scale tree planting program can potentially reduce the populations of the stenotopic grassland species in an area by eliminating their preferred habitat, i.e. more trees is not always better.

The best guide for tree plantings is to try and ascertain the historical distribution of the trees on a grassland. Use this as a basis for plantings in an attempt to replace trees lost. Additionally, if possible, plant trees that are native to the area. When trees are planted they should be protected from livestock by fencing. Such fencing can be especially beneficial if old homestead sites are fenced and new trees established in the exclosures. This protects existing trees and allows for replacements in one effort. Finally, trees should be planted on arid grasslands only when resources allow for a regular watering program in the first few years. Trickle irrigation can be especially effective in these situations.

WATER MANAGEMENT

Water is a precious resource in any grassland system and there are some basic management techniques that can enhance avian communities. Creating small ponds with overflow systems on stock watering tanks and with retention dams is generally useful. Placing floating ramps in stock tanks is also beneficial in that it allows birds and other animals that fall in to escape.

In many grassland areas water tables are being lowered severely by agriculture. One result is that many natural basins, such as playas, no longer hold water on a regular basis. This situation can be improved by deepening these basins. This approach has been applied successfully on the Commanche National Grassland (Morris Snider, per. commun.).

The proper use of fencing can benefit a wide variety of birds. One option is to fence half of any pond system. This will provide short vegetation adjacent to the water for the species that prefer this condition, e.g. Long-billed Curlew (Numenius americanus) (McCallum et al. 1977). Likewise, species that prefer the taller vegetation within the exclosures will also be accommodated. Alternatively, in areas with an abundance of ponds some could be fenced completely and others left open. This would accomplish the same result.

GRAZING

There is little doubt today that livestock grazing has caused major changes in wildlife populations in the western United States (Wagner 1978). The effects of grazing on bird communities, however, are not uniform or easily defined (Wiens and Dyer 1975).

Grassland bird communities evolved in conjunction with grazing. With the presence of an estimated 60 million bison (Bison bison) on the North American plains the grasslands were surely exposed to considerable grazing pressure (Owens and Myres 1973). In Alberta Owens and Myres (1973) suggest that the impact of bison grazing produced a mosaic of heavily grazed and trampled areas, where access for the bison was easy and/or which were close to water sources, interspersed with relatively undisturbed areas where access for the bison was more difficult or which were removed from water.

The preceding suggestion would basically explain the presence today in the same general grassland area of several stenotopic bird species that have different habitat preferences. Grazing, therefore, can be applied on separate units as appropriate to enhance the respective stenotopic species, as discussed earlier in the General Management Approach section. In fact, the similarity of the above historic habitat speculation and the management product based upon the stenotopic species concept presented herein is noteworthy.

SIZE OF MANAGEMENT BLOCKS

Another common trait of the National Grasslands is that they frequently contain blocks of lands interspersed with blocks of private lands. It is conceivable that land trades can be made that would result in larger, continuous blocks for both the National Grassland system and private landowners. Ideally, the public blocks should be connected by native habitat corridors. These same habitat patterns have been suggested for eastern forests as a mechanism for maintaining breeding populations of songbirds (Robbins 1979). Although data are lacking for North American grasslands, I feel that the same concept would apply. I do know that Mountain Plovers are absent from many small, isolated tracts of shortgrass prairie that otherwise look like ideal habitat.

TIMING OF HUMAN ACTIVITIES

There is considerable potential for enhancing grassland bird populations by restricting human activity on a seasonal basis. Human disturbance can be a major problem during the nesting season. In fact, within the nesting period, birds are most susceptible to abandonment of the nest during the early incubation period.

It is not realistic to restrict all human activity during the critical nesting period, but whenever it is possible to conduct activities at other periods of the year it should be done. Also, it is possible to apply this principle on a selective basis. Namely, restrict human activity during the nesting season in particularly critical areas. For instance, during the breeding season a "no activity zone" within the vicinity of sensitive raptor nests can be beneficial. This is already being done on some National Grasslands in areas with high concentrations of raptor nests.

This principle does not apply just to general public activity. Many types of routine maintenance work and major development can be done outside the breeding season. This should certainly be considered when the proposed activity can result in prolonged disturbance at a given site.

USE OF ARTIFICIAL STRUCTURES

There is an increasing tendency for land managers to incorporate the use of artificial structures into grassland management programs designed to benefit birds. While these structures have a place in management, their use should be viewed critically. A few examples will illustrate this point.

Perch-posts, consisting of telephone poles, have been placed in many grassland areas presumably to benefit raptors. They are considered beneficial in that they are sometimes used by hunting raptors. However, use per se does not mean that the structures are actually resulting in increased raptor populations. In fact, grassland raptors have evolved in an ecosystem with a historical paucity of perch sites. Consequently, they are adapted for hunting aerially and this technique apparently has served them well.

Some perch-posts have been placed in areas with high rodent populations. The thought is that this will increase raptor predation on the rodents, thus effecting a population control mechanism. Considering the reproductive rates of rodents versus the food consumption capabilities of raptors, I doubt the effectiveness of this approach. I certainly know of no data to support it.

On the negative side, however, perch-posts can be detrimental to some elements o bird communities. By attracting raptors to some sites, the result can be that the raptors inflict a disruptive or predatory influence upon other desired species. The best example of how an artificial perch site can have this effect is provided by Clai Braun (pers. commun.). He observed a situation where a Golden Eagle (Aquila chrysaetos) adopted a new power line pole as a hunting perch. The line was in the vicinity of a Sage Grouse (Centrocercus urophasianus) lek. Each morning, shortly after sunrise, the eagle would make an attack on the lek from its new perch. This particular lek decreased in numbers while the nearby leks remained stable, and the eagle activity is a suspected cause of the decline.

Artificial nest structures also are gaining in popularity and, like perch-posts, they should be evaluated critically. One problem with some artifical nest structures is that they attract the wrong species. For instance, American Kestrel (Falco sparverius) nest boxes are sometimes adopted by the introduced, eurytopic Starling (Sturnus vulgaris) (Hickey and Mikol 1979).

Artifical nest structures are especially popular with respect to management of large raptors on grasslands (Call 1979). Their use, however, should be carefully evaluated in terms of an overall community approach. For instance, I know of one cae on a National Grassland where a raptor nest structure was placed beside an active swift fox (Vulpes velox) den. While this may have been good for raptors, the good we probably negated by the detrimental impact upon the swift fox.

Because of the preceding problems, I would like to suggest some general guidelines for the application of artificial structures on grasslands. The primary use of these structures should be to temporarily replace lost habitat elements, i.e. the main emphasis should be upon replacing the natural habitat element. For instance, an artificial nest structure might be necessary in the interim between when a tree is lost and a new one grown.

Another use of artificial structures might be the actual movement of a nesting pair where the natural nest site is experiencing a particular problem. For instance, if a raptor nest is continually disrupted because of its proximity to a road an artifical nest might be used to entice the nesting birds to a more isolated location. In this case, however, the artificial nest should be replaced eventually with a natural nest site.

Finally, I want to stress that the use of artificial structures is a single-species management approach that is not always compatible with the overall avian community needs. Again, more is not always better. What counts is maintaining natural community relationships. This means that whenever the use of an artificial structure is contemplated, it should be evaluated carefully in terms of the potential role in the avian community. This dictates a detailed analysis of all the species present in the specific location under consideration. Alternatively, whenever an artificial structure is used, there should be a follow-up evaluation to determine whether the structure met the desired objective.

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BIRD HABITAT MANAGEMENT

Moderators: CARL D. MARTI
Weber State College
Ogden, Utah

CHARLES M. LOVELESS
Forest Environment Research
U. S. Forest Service
Washington, D. C.

EFFECTS OF GRAZING ON BIRD HABITATS

Ronald A. Ryder

Professor of Wildlife Biology
Colorado State University
Ft. Collins, Colorado 80523

ABSTRACT

Feeding on plants by various herbivores, especially livestock and big game but also by rodents, lagomorphs, insects and even some birds and reptiles, can alter vegetative communities as habitat for birds. Species composition of plants, density of stands, vigor, seed and insect production, and growth form of plants often change due to grazing. Removal of vegetative cover as well as trampling may expose soils to increased wind and water erosion. In shortgrass, for example, resultant gullies may provide new nesting habitat for rock wrens, rough-winged swallows, Say's phoebes, and barn owls while reducing nesting, escape and young-rearing habitat for species requiring denser stands of taller grasses such as meadowlarks and lark buntings. Just as some plants such as buffalo grass and blue grama can be considered "increasers" with grazing of shortgrass prairie so can horned

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KEYWORDS: grazing, birds, food, cover, water

In this paper I will attempt to draw together examples of the effects of foraging by various herbivores on avian habitats, review how the character of food, cover, and water can be modified, in certain cases for the betterment of some birds, in other cases to their detriment. Stress will be given to examples from the Great Plains, Rocky Mountains, and Great Basin. Hopefully, these examples may serve as bases for devising specific techniques that can be used by resource managers to better regulate grazing for the maintenance or improvement of avian habitats. Scientific names of plants and animals mentioned in the text are shown in Appendix I.

EFFECTS OF GRAZING ON INDIVIDUAL PLANTS

Grazing, browsing, and barking by various ungulates, rodents, lagomorphs, birds, eptiles and invertebrates can alter the growth forms of individual plants making ırubs and young trees grow bushier (hedged appearance) by removing terminal buds and timulating more lateral branching. Grazing of grasses at some seasons may markedly ffect tillering, basal branching from the lower nodes of the stem (Stoddart et al. 975). Some plants which evolved with grazing may have developed chemicals that timulate growth of grazed plants responding to saliva of herbivores (French 1979). lso, plants have evolved other chemicals, toxins, spines, and thorns to resist graz- ıg (Rosenthal and Janzen 1979).

Not only are above-ground parts modified by grazing but below-ground parts roots, corns and bulbs) are often reduced. However, Bartos and Sims (1974) found no ignificant differences in root mass of shortgrass plants resulting from different ıtensities of cattle grazing on the Central Plains Experimental Range or Pawnee Site ı northcentral Colorado. Conceivably, denser growing individual grasses and shrubs esulting from hedging might well provide better concealment for birds, better nesting ites and escape cover, and perhaps harbor more insects which can provide food for irds.

On the other hand, removal of forage by herbivores can so seriously reduce carbo- ydrate reserves of individual plants that their growth and reproduction can be etarded or, with continued overuse, less resistant plants can be killed (Stoddart : al. 1975). Loss of plants from a community alters vegetative density. Removal of oliage shortens the height and reduces the "bushiness" of individual plants causing lfferences not only in quality of living cover but also in residual or carry-over egetation (Weaver and Albertson 1940). Forbs and shrubs, unlike grasses, are not ell adapted to regenerate forage removal by grazing and browsing. However, certain ırubs can withstand winter use year after year whereas repeated clipping in the rowing season causes declines in forage yields and increased shrub mortality Holmgren and Hutchings 1972).

EFFECTS OF GRAZING ON PLANT COMMUNITIES

Grazing can alter the species composition of plant communities particularly where eavy use and drought causes retrogression, the shifting from climax communities to arlier seral stages (Klipple and Costello 1960, Brown and Schuster 1969). Thus, eavy use of true prairie can cause big bluestem to lose vigor, produce less annual rowth, and reduce or completely eliminate reproduction (Stoddart et al. 1975). otter and Krenetsky (1967) found that livestock grazing in New Mexico delayed the ormal succession of subclimax aspen to climax conifer types.

Typically, those plant species most preferred by livestock and those physiologi- ally and anatomically more susceptible to grazing injury will decrease or even isappear. Those species less preferred or more resistant will increase (Smith 1967, nith and Schmutz 1975). Thus, range managers refer to some plants as "decreasers" thers as "increasers." Still other plants may be able to invade communities follow- ıg or simultaneous with such changes in species composition. First invaders are sually more mobile annuals such as cheatgrass and Russian thistle but later erbaceous or woody annuals of low grazing value may invade (Ellison 1960). However, ven after 50 years of protection from grazing, species composition of some Sonoran esert plant communities did not appreciably change (Blydenstein et al. 1957) whereas oticeable changes occurred in others (Smith and Schmutz 1975). Changes in vegetative ensity are more pronounced than changes in species composition in protected and nprotected shortgrass prairie in northern Colorado (Bement 1968 and 1969, Hyder et l. 1975).

Depending on the types of herbivores involved, seasons and intensities of use, different mixes of grasses, forbs, and browse plants can result from grazing (Coupland 1979). The history of livestock grazing and big game populations and their habitats in the West have been well described by Wagner (1978a). Generally speaking, bison (Larson 1940, Peden 1972), bighorn, and cattle feed more heavily on grasses, deer (McKean and Bartman 1971) and goats on shrubs and trees, pronghorn (Hoover 1971, England and DeVos 1969) and domestic sheep more on forbs. Elk and horses feeding niches tend to overlap those of all of the above herbivores (Wagner 1978b). Continued early season grazing by cattle can cause many western grasslands to shift to more browse coverage, often for the betterment of deer (Stoddart et al. 1975). Springfield (1976) and Little (1977) noted that livestock grazing is important in the spread of juniper by dispersing seeds, trampling and reducing of competitive cover which encouraged juniper seedling establishment. Foraging by rodents and lagomorphs can profoundly affect vegetation of western rangelands (Norris 1950, Wood 1969, Rice and Westoby 1978).

Livestock grazing, rodent use, and control of wildfires are believed responsible for the spread of mesquite (Smeins et al. 1976, Reynolds 1958, Parker and Martin 1952, Glendening and Paulson 1955). In Texas, the rare golden-cheeked warbler apparently benefitted for awhile from the expansion of cedar-oak woodlands due to overgrazing (Pulich 1976). Braun et al. (1976) and Vale (1975) concluded, however, that overgrazing has not been largely responsible for the apparent expansion in range and dominance by big sagebrush.

Feral burros (McKnight 1958, Handley and Brady 1977) and horses (Olsen and Hansen 1977) can reduce plant densities, compete with livestock and big game for forage and probably alter avian habitat. Feral pigs seriously modify range and forest vegetation in the South, interfering with longleaf pine reproduction and destroying understory vegetation. In California and Hawaii feral pigs have greatly altered forest species composition (Wood and Barrett 1979). Particularly vulnerable to grazing are floras of oceanic islands, vegetation which evolved in the absence of native ungulates. Introductions of exotic big game and domestic livestock which have gone feral have destroyed or altered habitats vital to many endangered birds in Hawaii (Hartt and Neal 1940, Berger 1972) and in New Zealand (Howard 1964, Poole 1970, Halliday 1978).

EFFECTS OF GRAZING ON SOIL AND WATER

Trampling by ungulates can be beneficial or destructive to plants and their habitats and thus affect birds. Fall grazing of sagebrush-grass ranges by sheep can scatter newly-shed grass seeds and cover some seeds with soil, increasing chances of successful germination (Laycock 1967). Conversely, trampling can kill some plants and, along with removal of protective vegetation, expose soils to increased erosion by water, wind, and gravity (Stoddart et al. 1975). In northcentral Colorado, Klipple (1964) found greater herbage losses and mechanical damage to vegetation in shortgrass that was grazed early (May to August) compared to that grazed later (August to November). In the same area, plots heavily grazed by cattle had significantly lower water infiltration rates than did either light or moderately grazed areas (Rauzi and Smith 1973). Lusby (1979) recorded increased runoff and sediment yield with both cattle and sheep grazing of desert rangelands in western Colorado.

RESPONSES OF BIRDS TO GRAZING EFFECTS

Changes in plant vigor, growth form, and species composition due to grazing have frequently been related to the increase or decline of various species of birds (Townsend and Smith 1977). Braun et al. (1978) reported that at least 55 waterfowl studies have shown grazing detrimental to waterfowl production and that they knew of only one study (Burgess et al. 1965) that reported higher success of nesting ducks on moderately grazed areas than on idle lands. Ladd (1969), however, found greater

predator activity in long-established nonuse areas than in grazed areas on Valentine National Wildlife Refuge, Nebraska. He recorded greater duck use of grazed or mowed shorelines than of ungrazed and that ducks nested in grazed or mowed cover types as frequently in nonuse habitat.

Weller et al. (1958) considered a marked reduction of ducks and other waterbirds in a Utah marsh in large part due to grazing, mainly the destruction of old plant growth by trampling and newly grown vegetation by grazing but noted that some duck nests were destroyed by trampling. On Grays Lake National Wildlife Refuge in Idaho, two whooping crane chicks were alledgedly killed when "sat on by cattle" (National Audubon Society 1975).

Kirsch et al. (1978) believed that grazing (as well as haying) adversely affects many species of upland nesting birds in the northern Great Plains. In the Southwest, Brown (1978) concluded that heavy grazing by livestock removed critical perennial grass cover and caused serious declines, and in some cases complete elimination, of such species as lesser prairie chicken (see also Crawford and Bolen 1976), greater prairie chicken, and Montezuma quail (Fradkin 1979). Overgrazing is also thought to be detrimental to California quail (Leopold 1977) and masked bobwhite (Phillips et al. 1964) but moderate grazing might be beneficial to Gambel's quail (Gorsuch 1934) and scaled quail (Campbell et al. 1973).

Miller and Graul (1980), in a survey of states and provincial wildlife agencies, found that intensive grazing was considered the primary factor responsible for the decline of the Columbia sharp-tailed grouse and the second most important factor influencing the decline of the plains sharp-tailed grouse. Evans (1968) and Evans and Probasco (1977) stressed the detrimental effects of overgrazing on prairie grouse habitat. Kessler and Dodd (1978), however, found that Attwater's prairie chickens used grazed pastures more than ungrazed pastures as green herbaceous vegetation was made more available by grazing. Zwickel (1972) observed no significant differences in size of blue grouse broods nor density of birds in grazed compared to ungrazed study areas. He did find a higher proportion of successful hens on ungrazed areas. Twelve years of data gathered in North Dakota disclosed that American bitterns, marsh hawks and short-eared owls nested only in ungrazed, tall, dense grass and legume vegetation (Duebbert and Lokemoen 1977).

Some shorebirds seem to favor grazed areas, some ungrazed. On the Pawnee National Grassland in northern Colorado the mountain plover is most abundant as a nester on heavily grazed shortgrass (Graul 1973 and 1975), a habitat also preferred by the long-billed curlew on the Comanche National Grassland, Colorado (King 1978). In North Dakota, Kirsch and Higgins (1976) found better nesting success in upland sandpipers utilizing undisturbed areas than those using grazed mixed-grass prairie, while Skinner (1974, 1975) reported greater nest densities of the same species in grazed tall-grass prairie in Missouri than in idle areas.

During an intensive 5-year study of avian populations on the Pawnee Site in northcentral Colorado, we documented the preference of different species of birds for different densities and heights of vegetation, largely the result of varying intensities of grazing (Giezentanner 1970, Giezentanner and Ryder 1969, Porter 1973, Ryder 1972). Six 20-acre (8.1 ha) plots were censused weekly from April to September for 5 years. Each plot had been subjected to a different regime of grazing intensity or season of use for approximately 25 years (Table 1). The plot heavily grazed by cattle during the growing season had much shorter vegetation and more bare ground than those moderately or lightly grazed during the same time. See Hyder et al. (1975), Bement (1968 and 1969), Klipple and Costello (1960) for vegetative details. The winter-grazed areas had noticeably more fourwing saltbush than did summer-grazed plots. In brief, mountain plovers, horned larks and McCown's longspurs were more abundant nesters on the heavier used, summer grazed areas while chestnut-collared

longspurs, western meadowlarks and lark buntings were more abundant on lighter grazed areas (Table 2). All of the above species are ground nesters (Strong 1971). The Brewer's sparrow which nests in bushes was restricted to winter-use areas which had considerably more shrubs than summer-use areas. The mourning dove which was strictly a ground nester on our plots was only found in the winter-grazed areas.

TABLE 1.--Characterization of the six 20-acre (8.1-ha) avian plots grazed by cattle on the Central Plains Experimental Range, Colorado*

Plot	Season of Grazing	Intensity of Grazing	Vegetation
1	Summer	Heavy	Shortgrass, pricklypear, little litter
2	Summer	Light	Short-midgrass+, pricklypear, litter
3	Winter	Heavy	Short-midgrass, saltbush, locoweed, little litter
4	Summer	Moderate	Short-midgrass, few forbs, moderate litter
5	Winter	Moderate	Short-midgrass, saltbush, locoweed, litter
6	Winter	Light	Short midgrass, saltbush, heavy litter

*Adapted from Giezentanner (1970).
+Underlining indicates dominance.

TABLE 2.--Five-year average number of breeding pairs of birds per 20-acre (8.1 ha) plot on the Central Plains Experimental Range, Colorado, 1969-73

Species	Plots by Season and Intensity of Grazing			
	Summer-Heavy	Summer-Light	Winter-Heavy	Winter-Light
Horned lark	5.0	2.3	2.7	2.7
Lark bunting	0.0	5.1	3.7	4.0
McCown's longspur	4.0	3.2	0.0	0.0
Chestnut-collared longspur[1/]	0.0	0.1	0.0	0.0
Western meadowlark	0.1	1.2	1.1	1.5
Brewer's sparrow	0.0	0.0	2.0	2.9
Mourning dove[2/]	0.0	0.0	0.2	0.2
Mountain plover[3/]	1.3	0.0	0.0	0.0

1/ Chestnut-collared longspurs nested on plots only in 1970.
2/ Mourning doves nested on plots in 1969 and 1972.
3/ Mountain plovers utilized heavy-summer use area all 5 years.

Throughout the Pawnee National Grassland the horned lark (Boyd 1976), mountain plover (Graul 1973), nighthawk (Strong 1971) and killdeer all seemed well adapted to nesting on bare ground with sparse vegetation, habitat features typical of heavy grazing. Horned larks and mountain plovers regularly nest alongside piles of cow dung which are more abundant in heavy grazed areas. We found that gullies apparently exaggerated and accelerated in their development by intensive grazing provided nest

sites for rock wrens, Say's phoebes, barn owls, rough-winged swallows and, in some crevices, mourning doves.

Similarly, preferences by some avian species for sparse vegetation and others for dense vegetation have been noted in other grasslands. In Alberta fescue grasslands, horned larks and chestnut-collared longspurs were able to use heavily grazed areas unsuitable for Baird's sparrows and Sprague pipits which needed taller, denser vegetation (Owens 1971, Owens and Myres 1973). In Saskatchewan, the latter two species plus savannah sparrows preferred ungrazed mixed-prairie while horned larks, McCown's and chestnut-collared longspurs were most abundant in grazed pastures (Maher 1973 and 1979). In Missouri, an area of higher precipitation, Skinner (1974 and 1975) found only short-billed marsh wrens and Henslow's sparrows more abundant in ungrazed grasslands whereas eastern meadowlarks, bobolinks, grasshopper sparrows, red-winged blackbirds, and dickcissels were more abundant in grazed areas. He felt that more edge was created by uneven or selective grazing which resulted in greater diversity in grass height and density. In Arizona, Philips et al. (1964) concluded that masked bobwhite disappeared almost immediately following heavy cattle grazing in the 1870's and that Botteri's sparrow survived only in isolated colonies of grass "too tough for cows to chew." Cody (1966) and Creighton (1974) stressed the importance of grass height in habitat selection by grassland birds while Wiens (1969, 1973, 1974a, 1974b, 1976) and Wiens and Dyer (1975) have thoroughly covered the importance of residual vegetation and patchiness in habitat utilization by many grassland species.

The utilization of habitat other than grasslands also seems influenced by grazing. In desert-shrub types, Scott (1979) found fewer Crissal thrashers and brown towhees on grazed than on ungrazed areas of the Kofa National Wildlife Refuge, Arizona, apparently because heavy browsing by livestock reduced the abundance and vigor of jojoba shrubs. In northcentral Oklahoma, Overmire (1963) noted that populations of Bell's vireos and dickcissels were 50 percent lower on grazed than on ungrazed lands, apparently due to fewer suitable nesting sites.

In sagebrush-crested wheatgrass habitat in Idaho and Utah, Olsen (1974) showed a reduction in diversity and density of passerines with increased cattle grazing whereas Reynolds and Trost (1980) in similar types in Idaho grazed by sheep found diversity and density reduced in crested wheatgrass but concluded spring grazing by sheep was compatible with nesting and non-nesting bird populations in sagebrush-dominated habitats. Page et al. (1978) examined several vegetative types in Nevada and concluded that livestock grazing appeared to have negatively affected ground-nesters such as vesper sparrows, horned larks, savannah sparrows and western meadowlarks in sagebrush and meadow types. They found the effects of grazing most dramatic in aspen communities where Wilson's and MacGillivray's warblers decreased in numbers with near elimination of lower vegetative layers while American robins, mourning doves, and green-tailed towhees, which preferred more open habitat, increased.

Overbrowsing of a mixed-oak forest for 27 years by a confined herd of white-tailed deer, elk, and mouflon sheep on the Rachelwood Wildlife Reserve in southwestern Pennsylvania led to an even-aged forest lacking understory layers of shrubs and saplings (Butler 1979). This use adversely affected species such as Kentucky and hooded warblers, indigo bunting, and rufous-sided towhee which fed and nested in the lower vegetative strata. However, other species such as woodpeckers, eastern wood pewee, tufted titmouse, American robin, and chipping sparrow, which were either trunk-foragers, cavity-nesters, or ground-foragers, benefitted.

In northeastern Ohio, Dambach (1944) found breeding birds four times more abundant in ungrazed woodlands than in grazed after 10 years of study. He noted only 61 kinds of vascular plants on the grazed areas compared to 124 on the ungrazed.

Also in Ohio, Good and Dambach (1943) noted little effect of grazing on hole-nesters such as chickadees, titmice and woodpeckers whereas tree- and shrub-nesting species were reduced. In Colorado, cattle damage nest trees of raptors on the Pawnee National Grassland by their rubbing and trampling (Olendorff and Stoddart 1974).

In the West, riparian habitats are especially vulnerable to overgrazing (Platts 1979, Rucks 1978, Severson and Boldt 1978, Thomas et al. 1979, U.S. Forest Service 1979, Crouch 1961, 1978, 1979a, 1979b). Benson (1979) believed marsh hawks as well as several passerines were adversely affected by riparian grazing. Other participants in this workshop, particularly Szaro, Tubbs and Ohmart, will discuss riparian grazing in greater detail.

EFFECTS OF GRAZING ON THE FOODS OF BIRDS

Livestock, big game, rodents and lagomorphs, some reptiles, and insects by eating various range and forest plants alter habitat affecting types and abundance of foods for birds. On the Pawnee Site in Colorado, Flinders and Hansen (1975) found black-tailed jackrabbits, important food of golden eagles, most abundant in pastures lightly or moderately grazed by cattle in the summer, whereas desert cottontails were more abundant in moderately grazed, summer or winter-use pastures where fourwing saltbush provided more cover. In southern Arizona, Taylor et al. (1935) noted that jackrabbits were more abundant in overgrazed areas.

Phillips (1936) observed a reduction in rodent and rabbit numbers when range was heavily overgrazed, although some small mammals preferred moderately overgrazed areas. Smith (1940) found that rodent and invertebrate numbers varied with the intensity of grazing. Koford (1958) associated prairie dog and various rodent increases with livestock grazing. In a Utah study (Black and Frischknecht 1971), deer mice were most abundant in heavily grazed seeded areas and native areas with light cover whereas Great Basin pocket mice and western harvest mice were most abundant in areas of relatively light grazing. Undoubtedly, grazing can affect the abundance and availability of small mammals and insects that serve as prey for many species of birds.

Grazed areas in Missouri normally have higher populations of grasshoppers than ungrazed areas (Shotwell 1958, Skinner 1975). Both Baldwin (1971 and 1973) and Maher (1976) stressed the importance of grasshoppers in the diets of grassland birds. Early successional stages of grasslands normally have more annual grasses and forbs which produce an abundance of seeds for reproduction. Rodents can compete directly with rangeland birds for available insects and seeds.

Piles of livestock dung, mainly from cattle but sometimes from horses, seem attractive to horned larks and mountain plovers not only for a windbreak next to which to nest but probably also as a source of insects and partially digested plant materials. Captive horned larks I have raised were especially fond of tearing dried "cow chips" apart, apparently finding food items. In the fall, mountain plovers frequently flock in heavy-use areas such as around windmills where cattle dung is unusually abundant. Whether they find food there or camouflaging as they crouch among the piles is unknown. The habits of cowbirds and cattle egrets following grazing animals to catch insects they disturb are well known.

CONCLUSIONS

The effects of grazing on avian habitats vary from area to area. In areas of higher precipitation, grazing may be highly desirable to open up "roughs" and provide more diversity and patchiness. In areas of low precipitation, protection from grazing may be necessary to produce habitat necessary for a species that was benefitted by grazing in a more humid area. Effects of soil, slope, and exposure along with amounts and seasonal distribution of precipitation may be far more

important than grazing in affecting food, cover, and water for birds. However, management of grazing can no doubt be a powerful tool in regulating the types and quality of habitat that can be provided nongame birds.

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APPENDIX I

List of Scientific Names

PLANTS

Juniper	*Juniperus* sp.
Longleaf Pine	*Pinus palustris*
Cheatgrass	*Bromus tectorum*
Big Bluestem	*Andropogon gerardi*
Crested Wheatgrass	*Agropyron cristatum*
Western Wheatgrass	*Agropyron smithii*
Needle-and-thread	*Stipa* sp.
Blue Grama	*Bouteloua gracilis*
Buffalo grass	*Buchloe dactyloides*
Fourwing Saltbush	*Atriplex canescens*
Russian Thistle	*Salsola kali*
Locoweed	*Oxytropis* sp.
Jojoba	*Simmondsia chinensis*
Mesquite	*Prosopis* sp.
Pricklypear	*Opuntia* sp.
Aspen	*Populus tremuloides*
Big Sagebrush	*Artemisia tridentata*

BIRDS

Cattle Egret	*Bubulcus ibis*
American Bittern	*Botaurus lentiginosus*
Golden Eagle	*Aguila chrysaetos*
Marsh Hawk	*Circus cyaneus*
Blue Grouse	*Dendragapus obscurus*
Plains Sharp-tailed Grouse	*Pedioecetes phasianellus jamesi*
Columbian Sharp-tailed Grouse	*P. p. columbianus*
Greater Prairie Chicken	*Tympanuchus cupido*
Attwater's Prairie Chicken	*T. c. attwateri*
Lesser Prairie Chicken	*Tympanuchus pallidicinctus*
Scaled Quail	*Callipepla squamata*
California Quail	*Lophortyx californicus*
Gambel's Quail	*Lophortyx gambelii*
Montezuma Quail	*Cyrtonyx montezumae*
Masked Bobwhite	*Colinus virginianus ridgwayi*
Whooping Crane	*Grus americana*
Killdeer	*Charadrius vociferus*
Mountain Plover	*Charadrius montanus*
Long-billed Curlew	*Numenius americanus*
Upland Sandpiper	*Bartramia longicauda*
Mourning Dove	*Zenaida macroura*
Barn Owl	*Tyto alba*
Short-eared Owl	*Asio flammeus*
Common Nighthawk	*Chordeiles minor*
Woodpeckers	Family Picidae
Say's Phoebe	*Sayornis saya*
Eastern Wood Pewee	*Contopus virens*
Horned Lark	*Eremophila alpestris*
Rough-winged Swallow	*Stelgidopteryx ruficollis*

Chickadees	*Parus* sp.
Tufted Titmouse	*Parus bicolor*
Short-billed Marsh Wren	*Cistothorus platensis*
Rock Wren	*Salpinctes obsoletus*
Crissal Thrasher	*Toxostoma dorsale*
American Robin	*Turdus migratorius*
Sprague Pipit	*Anthus spragueii*
Bell's Vireo	*Vireo bellii*
Golden-cheeked Warbler	*Dendroica chrysoparia*
Kentucky Warbler	*Oporornis formosus*
MacGillivray's Warbler	*Oporornis tolmiei*
Hooded Warbler	*Wilsonia citrina*
Wilson's Warbler	*Wilsonia pusilla*
Bobolink	*Dolichonys oryzivorus*
Eastern Meadowlark	*Sturnella magna*
Western Meadowlark	*Sturnella neglecta*
Red-winged Blackbird	*Agelaius phoeniceus*
Cowbirds	*Molothrus* sp.
Indigo Bunting	*Passerina cyanea*
Dickcissel	*Spiza americana*
Green-tailed Towhee	*Pipilo chlorurus*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Brown Towhee	*Pipilo fuscus*
Lark Bunting	*Calamospiza melanocorys*
Savannah Sparrow	*Passerculus sandwichensis*
Grasshopper Sparrow	*Ammodramus savannarum*
Baird's Sparrow	*Ammodramus bairdii*
Henslow's Sparrow	*Ammodramus henslowii*
Vesper Sparrow	*Pooecetes gramineus*
Botteri's Sparrow	*Aimophila botterii*
Brewer's Sparrow	*Spizella breweri*
Chipping Sparrow	*Spizella passerina*
McCown's Longspur	*Calcarius mccownii*
Chestnut-collared Longspur	*Calcarius ornatus*

MAMMALS

Desert Cottontail	*Sylvilagus audubonii*
Black-tailed Jack Rabbit	*Lepus californicus*
Prairie Dog	*Cynomys* sp.
Great Basin Pocket Mouse	*Perognathus parvus*
Western Harvest Mouse	*Reithrodontomys megalotis*
Deer Mouse	*Peromyscus maniculatus*
Horse	*Equus caballus*
Burro	*Equus asinus*
Pig	*Sus scrofa*
Elk	*Cervus elaphus*
White-tailed Deer	*Odocoileus virginianus*
Pronghorn	*Antilocapra americana*
Cattle	*Bos taurus*
Bison	*Bison bison*
Goat	*Capra hircus*
Bighorn	*Ovis canadensis*
Domestic Sheep	*Ovis aries*
Mouflon Sheep	*Ovis ammon*

MANAGEMENT CONSIDERATIONS FOR NONGAME BIRDS IN WESTERN WETLANDS

David E. Capen and Jessop B. Low

Wildlife Biology Program, University of Vermont
and Department of Wildlife Science, Utah State University

ABSTRACT

Wetland habitats are of special value in the western United States. We describe four types of wetlands which are distinguished by degree of water permanence, soil salinity, and composition of aquatic vegetation. Both saline and freshwater marshes provide nesting habitats for a unique variety of grebes, pelicans, wading birds, shorebirds, and gulls. Saline flats, often flooded only seasonally, are a valuable habitat resource for migrating birds. Good wetland management should provide for a water supply which is adequate both in quantity and quality, an interspersion of open water and marsh vegetation, and a mixture of vegetative layers. Management practices which may enhance habitat for birds include manipulating water-levels; maintaining isolated stands of emergent vegetation; creating islands and furrows; altering the composition of emergent vegetation; and controlling livestock access. These practices benefit most wetland birds, game and nongame, but may be selectively employed to favor certain groups of nongame species if management practices dictate.

KEYWORDS: Aquatic plants, colonial birds, cormorants, cranes, grebes, gulls, marshes, nongame birds, pelicans, saline soils, shorebirds, wading birds, wetlands, wetland management.

Water is a critical and a limited resource in the western United States. Such a myriad of demands--agricultural, industrial, residential, recreational, and energy-related--threatens water resources in the West that the interests of wildlife, particularly nongame wildlife, are persistently threatened. Wetland habitats, then, should be placed at a premium, preserved whenever possible, and managed intensively.

Our purpose is to encourage wetland managers to consider nongame birds in the development and implementation of management plans. The specific objectives of this paper are (1) to describe representative western wetland habitats as they are characterized by their dominant plant species; (2) to discuss selected nongame birds which

may be of special interest; (3) to outline some principals of good wetland management; and (4) to address some management options where special consideration should be given to nongame birds.

In brief, our contention is that good management of wetlands is good management for nongame birds. A graphic illustration of this conclusion can be observed by visiting the well-known Bear River marshes near Brigham City, Utah. Spanning the main street of Brigham City is a large arch which reads "Welcome to Brigham--gateway to the world's greatest game bird refuge." A short distance from Brigham City visitors encounter a U.S. Fish and Wildlife Service sign welcoming them to Bear River Migratory Bird Refuge. This is the same "great game bird refuge" which merited a chapter in a recent book describing Roger T. Peterson's favorite bird-watching sites in North America (Harrison 1976). The managers of Bear River Refuge have earned this dual distinction by managing their wetlands well and considering the needs of game and nongame birds alike.

Wetland Types

Wetland habitats exist where the water table is at, near, or above the surface long enough each year to promote the formation of hydric soils and support the growth of hydrophytes (Sather 1976). The classification of wetland types has become a science in itself, and has evolved to a point where wetlands and deep-water habitats throughout the United States are currently being classified and inventoried using a single comprehensive approach (Sather 1977). According to this latest classification system, the wetlands included in the scope of this paper may be described as "persistent or nonpersistent emergent wetlands in the palustrine ecological system." While that may be a suitable classification for a large-scale inventory, we find it more convenient to abbreviate the early system of Martin et al. (1953) and restrict our description of wetlands to four habitat types: saline flats, saline marshes, shallow fresh-water marshes, and deep fresh-water marshes.

Plant communities of these habitat types are relatively simple, and vegetational zonation usually follows a course dictated by soil salinity (Bolen 1964). A typical transition from communities of saline flats to deep, fresh-water plant complexes may be illustrated with less than a dozen species of plants.

Saline flats, characteristically innundated only seasonally, are usually vegetated by glasswort (*Salicornia rubra*), one of the most halophytic wetland plant species. Saltgrass (*Distichlis stricta*) frequently borders saline marshes, and may mix with or be replaced by rushes (*Juncus balticus*), sedges (*Carex* spp.) and spikerushes (*Eleocharis* spp.) as salinity moderates.

Emergent aquatics give saline and shallow fresh-water marshes their character and provide the most commonly-used nesting cover for birds. Olney's bulrush (*Scirpus olneyi*) tolerates the greatest salt content, but a similar species, alkali bulrush (*S. paludosus*) is more widespread. As the environment becomes less halophytic, hardstem bulrush (*S. acutus*) and cattail (*Typha latifolia* or occasionally *T. angustifolia*) are the common emergents.

Deep fresh-water marshes are characterized by submergent plants. Some of these plants provide abundant seeds which are utilized as food by waterfowl. They also harbor macroinvertebrates, a most important class of food item for many wetland bird species. The most salt-tolerant common submergent plant is widgeongrass (*Ruppia maritima*), often found in association with an algae called muskgrass (*Chara* sp.). Sago pondweed (*Potomogeton pectinatus*) is the most widespread submergent plant in western wetlands, and is considered most desirable because of its value as a food plant for waterfowl. This species is moderately

submergents, common in northcentral and northwestern wetlands, are noticeably absent in western marshes.

Millar (1969, 1973, 1976) reviewed the ecology of plant associations in western Canada. Bolen's (1964) monograph dealt with the plant ecology of a spring-fed salt marsh in Utah, and was supplemented by McKnight and Low (1969) with a later study of the same marsh following impoundment. The influence of salinity on growth and reproduction of marsh plants was investigated by Kaushik (1963), Teeter (1965) and Mayer and Low (1970). A thorough review of marsh plants and their management can be found in the bibliography prepared by Wentz et al. (1974).

Wetland Birds

Birds which visit wetlands in the West during migration are too numerous to mention; a list of migrants would easily exceed 200 species. We will discuss only 23 species of nongame birds, representing 11 families, which might be of special concern to wetland managers because they depend on western wetlands for nesting habitat; because they are rare species; and/or because they are especially sought by bird-watching enthusiasts.

Four species of grebes nest in deep-water western marshes, but the western grebe (*Aechmophorus occidentalis*) attracts the most attention. Recent declines in the numbers of this species have prompted studies by Nuechterlein (1975), Lindvall (1976) and Ratti (1977). Western grebes nest near the edge of stands of emergent vegetation or by building a nest from a mound of submergent plants. They commonly nest in colonies and are notorious for nesting late in the season, thus being threatened by low water levels in late summer.

Eared grebes (*Podiceps nigricollis*), horned grebes (*Podiceps auritus*), and pied-billed grebes (*Podilymbus podiceps*) characteristically build floating nests of submergent plants in deep-water marshes. Glover (1953) studied the pied-billed grebe and published one of the few studies of these less common grebe species.

White pelicans (*Pelecanus erythrorhynchos*) are widely distributed but only locally common throughout the western United States and Canada (Ryder and Grieb 1963, Vermeer 1970, Boeker 1972). They feed in shallow-water and deep-water wetland areas but nest on isolated islands. Adult pelicans may fly hundreds of miles each day between nesting sites and feeding areas (Low et al. 1950). Nesting colonies of white pelicans are especially susceptible to nest predation and human disturbance (Johnson and Sloan 1976). The behavior and ecology of this species have been described by several authors (Schaller 1964, McCrow 1974, Knopf 1979).

Double-crested cormorants (*Phalacrocorax auritus*) have long been considered by many in the manner which Mitchell (1977) credited to an earlier author: "God no doubt had his reasons for creating each living thing, but when he created the cormorant, he did himself little credit." Numbers of this species have declined recently in many inland locations of the West, and now there is concern for the few remaining nesting colonies. Although double-crested cormorants commonly nest in trees, island locations are often selected in wetlands where arboreal sites are not present.

Herons, egrets, and ibises are collectively referred to as wading birds and may be especially abundant because they nest sometimes in colonies of 1000 or more breeding pairs. The great blue heron (*Ardea herodias*) is the most conspicuous of these birds. This species characteristically selects arboreal sites for rookeries, but may build nests in tall emergent vegetation in locations where suitable trees are lacking. Black-crowned night herons (*Nycticorax nycticorax*) select nest sites in a similar fashion. This species, however, commonly suffers egg predation by other birds and

mammals when nesting in emergent vegetation (Wolford and Boag 1971). Snowy egrets (*Leucophyx thula*) often join great blue herons and black-crowned night herons in mixed nesting colonies, although these egrets are sometimes solitary nesters. A less abundant species in western marshes is the common egret (*Casmerodius albus*).

The white-faced ibis (*Plegadis chihi*) is another colonial-nesting wading species which has been the subject of recent concern because several major nesting colonies in the West have declined in numbers. Information on the distribution and biology of this species has been reported by a number of investigators (Ryder 1976, Kotter 1970, Kaneko 1972, Capen 1977). Pesticides may have been responsible for reduced numbers of nesting white-faced ibises (Capen 1977), and a concern for the effects of pesticides continues because much of the population of this species winters in Mexico where the use of agricultural chemicals is not regulated as strictly as in the United States.

Mixed nesting colonies of herons, egrets, and ibises are occasionally observed in western marshes. Such colonies are usually located in isolated stands of emergent vegetation, and the same location is often selected for nesting in consecutive years. The great blue heron seems to show the strongest fidelity to a particular colony site from year to year, while the other wading birds appear to exhibit a greater response to current habitat conditions in selecting the site for a nesting colony.

Sandhill cranes (*Grus canadensis*) are only locally common throughout the West (Drewien and Bizeau 1974). The breeding biology of this species has been investigated in some detail (Littlefield 1968, Littlefield and Ryder 1968, Drewien 1973, Lewis 1977). The cranes nest in large shallow-water marshes that are isolated from human activity and are close to upland meadows used for feeding. This species has attracted recent attention as a foster parent for translocated endangered whooping cranes (*Grus americana*) (Drewien and Bizeau 1977).

Rails are secretive birds and are not observed often. However, their distinctive calls indicate their presence in a shallow-water marsh. Two species, the Virginia rail (*Rallus limicola*) and the sora (*Porzana carolina*), will occur in most marshes where dense emergent plants exist. Management concerns for the Virginia rail are presented by Zimmerman (1977), and management of the sora is discussed by Odom (1977).

Shorebirds are the most numerous species in western wetland habitats, but most are present only as they migrate to and from arctic nesting areas. Several species, however, do depend on western marshes during the breeding season. Snowy plovers (*Charadrius alexandrinus*) nest occasionally near the water's edge where little or no vegetative cover occurs. The willet (*Catoptrophorus semipalmatus*) is a more common and conspicuous species which selects a similar nest site. Another interesting shorebird is one which feeds in shallow marshes but nests in upland habitats, the long-billed curlew (*Numenius americanus*). Two shorebirds have recurved bills which they use to stir up food items from mud bottoms in shallow water. These two species are landmark birds of western marshes, the American avocet (*Recurvirostra americana*) and the black-necked stilt (*Himantopus mexicanus*). Gibson (1971) reported on the breeding biology of the avocet. A review of shorebird management was compiled by Jurek and Leach (1977)

California gulls (*Larus californicus*) frequent marshes as well as lakes throughout the West. They commonly prey on eggs of other birds, and are often regarded as undesirable predators. These gulls usually nest in large colonies and build nests on the ground. A friendlier species is Franklin's gull (*Larus pipixcan*) which also nests in colonies. This species constructs nests in emergent vegetation and may mix with colonies of wading birds. Forster's tern (*Sterna fosteri*) is another larid found in inland wetlands, but unlike the gulls, it is a solitary-nesting species and selects hummocks of vegetation for nesting sites.

Principals of Wetland Management

Before discussing specific management practices which may be employed in wetland areas, we will identify three general guidelines for managing wetlands.

1. *Ensure an adequate supply of water, both in quantity and quality.* Water control structures and legal easements may represent the first step towards implementing this objective. Water levels must be maintained throughout the breeding season with special consideration for late-nesting species like western grebes. Christiansen and Low (1970) studied water requirements of marshlands in northern Utah and recommended standards for both quantity and quality of water supplies. The quality of a water supply may be particularly important to monitor because declining water quality may lead to insidious deterioration of wetland habitats.

2. *Provide favorable interspersion of open water and marsh vegetation.* Weller and Spatcher (1965) concluded that maximum diversity and numbers of wetland birds were reached when a cover-water ratio of about 50:50 occurred. A cover-water ratio of 65:35 might be considered optimum as well (Michot 1974), because the proper interspersion of vegetation and water is probably a more important factor than the composite ratio (Weller et al. 1958).

3. *Encourage vertical interspersion of vegetation in addition to horizontal diversity.* A mixture of trees and shrubs along marsh edges, low shallow emergents, tall robust emergents, and submerged plants will further enhance the diversity of wetland birds (Weller and Spatcher 1965).

Management Practices for Wetlands

Wetland management practices have been the subject of research endeavors for decades, as described in review papers by Sanderson and Bellrose (1969) and Bellrose and Low (1978). Researchers have experimented with management practices designed to retard plant succession, control undesirable plants, encourage desirable vegetation, increase vegetative interspersion, and enhance fertility, among other objectives.

Water-level control is probably the most important technique in the management of wetlands and is a technique which has been studied extensively (Bourne and Cottam 1939, Wolf 1955, Johnsgard 1956, Kadlec 1962, Anderson and Glover 1967, Meeks 1969). Control of water levels may be used to increase or decrease salinity; to stimulate germination and growth of moist-soil plants; to enhance the production of invertebrates; to clear-up turbidity; to recycle nutrients; and to control plants, fishes, mosquitos, muskrats, and disease. Surprisingly though, little is known about the effects of drawdowns in wetlands with saline soils, and this is an area where research is needed.

Additional management practices which have been employed in wetlands to achieve some of the above objectives include burning to control dense emergents such as cattails and phragmites (*Phramites communis*) (Cartwright 1942, Ward 1942, Nelson and Dietz 1966); using explosives to create potholes which increase the interspersion of cover and water (Strohmeyer and Fredrickson 1967); controlling carp and other fish to encourage the growth of submerged vegetation (Anderson 1950, Robel 1961); planting desirable aquatic vegetation (Kadlec and Wentz 1974); and of course, ditching, diking, and dredging to enhance interspersion of vegetation and water and to make water-level control possible. Linde (1969) reviewed these and other techniques for wetland management and Hine (1971) compiled an extensive bibliography on the ecology and management of wetlands.

Considerations for Nongame Birds

Special consideration should be given to management practices if some of the above bird species are to be featured. Colony-nesting birds are particularly sensitive to changes in habitat conditions after establishing a nesting site, because factors which might lead to nesting failures affect entire colonies. Wading birds have nidicolous young, thus the nesting period and the birds' reliance on a specific nest site lasts for 2 months or longer. This is a consideration for cormorants, gulls, and terns as well.

Colonial waterbirds usually select isolated locations for the establishment of their colonies. Wetland managers should insure the maintenance of these isolated conditions by sustaining water-levels throughout the nesting season; restricting human activities; and preventing access to grazing animals.

Intensive wetland management may involve the creation of nesting islands, earthen furrows, and perching or nesting structures. Small islands are used as nesting sites by double-crested cormorants, gulls, and some shorebirds. Long, earthen furrows which follow the contours of the marsh have been constructed in shallow water areas of the Bear River Migratory Bird Refuge. These furrows, which are just a few feet wide and only inches above water, provide attractive nesting sites for American avocets, black-necked stilts, and other shorebirds (Mobley 1976). However, these structures may attract mammalian predators and function as virtual traps for the birds which nest on them. Islands and furrows should be located away from predator populations if possible.

Predatory birds may be attracted to wetland habitats by erecting artificial perching structures, preserving large trees near wetlands, or planting woody species. Again, these practices create a dilemma for the manager because the predators may exploit, as prey, other birds which have been attracted to the wetland.

The wetland manager is often confronted with decisions concerning the well-being of a wildlife community which is often dependent on "artificial" wetland habitats--not natural systems. These habitats are all too often dependent on "used-over" or "left-over" water, making the system even less natural. The managers task is a difficult one, then, and should involve a program of assigning priorities to selected species or groups of species.

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USES OF SHELTERBELTS BY BIRDS

J. Frank Cassel and John M. Wiehe

Professor and Research Associate
Zoology Department, North Dakota State University
Fargo, North Dakota 58105

ABSTRACT

Many tree plantings of various sizes, some a century old, supplement the very limited natural woodland of North Dakota. Twenty-four species of birds have been found breeding in over 10% of the 81 rural plantings studied. Only Brown Thrasher, Mourning Dove, and Vesper Sparrow occurred in over half of them. Many species use the plantings with little regard for east-west location, age over five years, or number of rows or size. In a particular community, the number of species and their density seem to increase with the age and size of the planting. Some species live entirely within the plantings, others may merely nest there or use it only for singing. No species is resident in such plantings in the winter, but a few visit them for shelter and foraging.

KEYWORDS: Shelterbelt, tree claim, tree planting, avian community, winter birds, breeding birds, North Dakota.

WHAT IS A SHELTERBELT?

Of the over 190 species of birds known to have bred in North Dakota in recent years, at least 64 of them have been found breeding in shelterbelts or tree claims. Little (2%) of North Dakota's vast area (70,594 sq. mi.) is forested. Native deciduous woodlands cover limited upland areas in the northeastern and in the southeaster parts of the state and in the Turtle and Killdeer Mountains. An open forest of Ponderosa Pine covers about 1600 ha near the Little Missouri River in the southwest. Otherwise native deciduous forests are restricted to major water courses and to near by draws leading to them. On the other hand, one is seldom out of sight of trees he state. Trees have been planted in towns as windbreaks, near ect fields. (See Stewart 1975.)

planted trees near their homesteads. In the mid-thirties (Dust Bowl years) the Prairie States Forestry Project was initiated by the Soil Conservation Service, and "shelterbelts" began to appear on many farms across the state. Most of these were multirow belts (9-12 rows) although some three-row belts were planted. Many land owners also have "wildlife plantings" which often are well over 12 rows. In the fifties some single row belts were planted at intervals across the field rather than just on the north or west sides.

Recently, particularly with the advent of center-pivot irrigation, many shelterbelts are being removed. The history and trends are reviewed in the 1976 Proceedings of the Symposium on Shelterbelts of the Great Plains edited by R. W. Tinus (1976).

Over the past 25 years numerous breeding and winterbird surveys have been made in North Dakota tree claims and shelterbelts. These habitats are tailor-made for successional studies. Not only can the change in avian communities be followed as a particular belt matures, but the communities associated with different aged belts can be studied the same season.

The shape of the belt and its isolated nature enhance complete counts of its avian populations. Differences in populations in different belts, each unique in time and space, are instructive. This paper, however, emphasizes the general influence of tree plantings on the birds of the area.

WHERE ARE THE TREE PLANTINGS?

Most counts have been done in eastern North Dakota, in Cass County near Fargo, and Trail County near Mayville (97th parallel) (33 breeding counts in 15 belts, 24 winter counts in 8 belts), and in Barnes County north of Valley City (98th parallel) (40-41 counts in 21 belts). Increasing concern for the North Dakota environment stimulated by proposed irrigation and mining projects has motivated studies which are beginning to provide data across the state. Extensive counts of birds in tree plantings have been made by the field biology team working out of the Missouri-Souris Project Office at the U. S. Water and Power Resources Service (Bureau of Reclamation) in Bismarck. Special thanks are due Richard McCabe and his team, especially Martha Carlisle, Tom Gatz, Don Treasure, and Mike Johnson who supplied me with computer printouts of the birds they observed in tree plantings in 1978 and 1979 in Benson and Eddy Counties (99th parallel) during their random quarter counts in connection with studies related to the Garrison Diversion Project.

Two tree plantings in Morton County (101st parallel) have been studied by Bill Lynott of the North Dakota Game and Fish Department who provided me with his 1979 results.

Three belts were studied in Dunn County (102nd parallel) in 1975 and two in Billings County (103rd parallel) in 1979. Obviously, the few studies in the west do not provide the coverage that the many in the eastern part of the state give, but at least the species once observed indicates occurrence during that season. Studies in Morton and Billings Counties are continuing, and recently studies have begun in several belts in Oliver County (101st parallel).

Over the years many students have been involved in North Dakota State University studies, some of which have been published in AMERICAN BIRDS (AUDUBON FIELD NOTES). Weiser and Hlavinka (1956), Hegstad (1965), Maland and Argyle (1965), Franson (and Lutgen) (1965), Moore, Strand, Voight and Kroodsma (1966), Buresh, Fortney, Moen and Jay Cassel (1967) and Resell (1973) have published breeding bird counts. Clarens (1963) has included breeding counts in a thesis. Voorhees, Baumann, Carlisle,

Crooke, Gulke, and Jacobsen participated in breeding counts reported by Cassel, Voorhees and Whitman (1976). Rotzien (1963), Renhowe, Anderson, and Issacson did winter counts. Greg Hiemenz, Nestor Hiemenz, Wallace and Wiehe have been involved i recent studies in Billings County.

BREEDING BIRDS

The concentration of breeding pairs within the limited isolated habitat elevate the density. Density is figured in terms of pairs per square kilometer and pairs pe 100 acres, up to 1000 males/100 a. (2471/km^2) (Maland and Argyle 1965:605). For strip comparisons we also state the densities in pairs per half mile of belt (Half mile rather than mile because few belts are over a half mile long. They are often shorter.). Seventy-three males/0.5 mile seems a more reasonable figure for comparison than 1000 males/100 a. (Maland and Argyle 1965:605). Suedkamp (1976) discusses the tree and shrub species used in shelterbelts. Those most common in our belts are shown in Table 1. Scientific names of plants and animals mentioned in the text and tables are given in Appendix I.

Table 1.--Major Woody Species of North Dakota Shelterbelts

Trees		Shrubs
Tall	Intermediate	
*American Elm	*Boxelder	*Plum and Cherry (Prunus spp.)
*Green Ash	*Siberian Elm	*Caragana
Hackberry		Honeysuckle
Cottonwood (old belts)	Willow	*Russian Olive
		Lilac
		Cotoneaster
		Buffalo-berry
		Golden Currant
		Woods Rose

*Most frequent species

Of the 64 species of birds recorded using shelterbelts during the breeding season, only three species (Brown Thrasher, Mourning Dove, and Vesper Sparrow) were found in more than half the study areas, while 24 species were found in more than 10% of the belts (Table 2).

Table 2.--Breeding Birds of Shelterbelts*

Species	f+	Age of Shelterbelts in Years						Rows in Shelterbelts				
		0-4	5-9	10-19	20-39	40-59	> 75	1	2-3	4-13	14-20	> 20
Brown Thrasher	.59	.07	.63	.77	.67	1.0	0.5	.4	.75	.61	.38	1.0
Mourning Dove	.58	0	.56	.62	.87	.75	.67	.2	.38	.63	.5	1.0
Vesper Sparrow	.50	.79	.81	.31	.4	.25	.17	.9	.63	.49	.25	.25
Least Flycatcher	.47	0	.25	.77	.6	.25	.67	.1	0	.57	.38	1.0
Eastern Kingbird	.44	0	.25	.46	.67	.75	1.0	.4	.38	.39	.25	1.0
Black-billed Cuckoo	.42	0	.44	.42	.6	.5	.83	.2	.38	.35	.38	1.0
Yellow Warbler	.42	0	.25	.62	.6	.25	.5	.1	0	.53	.25	.75
American Goldfinch	.42	.21	.69	.38	.4	.5	.17	.7	.38	.35	.25	.75
Gray Catbird	.41	0	.38	.46	.67	0	.5	0	.13	.55	.38	.25
Clay-colored Sparrow	.41	.43	.69	.42	.2	.5	0	.7	.63	.35	.25	.5
American Robin	.37	0	.31	.42	.73	.25	.17	.2	.13	.41	.25	1.0
Brown-headed Cowbird	.31	0	.25	.35	.4	.5	.5	.2	.25	.25	.25	1.0
Red-winged Blackbird	.30	.14	.38	.23	.3	.5	.17	.2	.38	.25	.13	.5
Common Grackle	.27	0	.06	.35	.67	.25	.3	0	.13	.3	.25	.5
Common Yellowthroat	.23	.07	.06	.15	.27	.5	1.0	.3	.13	.22	.13	1.0
House Wren	.22	0	0	.15	.19	1.0	.67	.1	.25	.12	.5	1.0
Western Kingbird	.21	0	.13	.23	.13	.5	.67	.2	.25	.2	.13	.5
Northern Oriole	.21	0	0	.19	.27	0	.83	0	0	.22	0	.75
Song Sparrow	.19	0	.25	.04	.07	.75	.83	.1	.38	.16	0	.5
Horned Lark	.16	.79	.25	0	0	0	0	.4	.5	.14	0	0
Western Meadowlark	.16	.21	0	.15	.13	.75	0	.3	.25	.1	.13	.5
Common Flicker	.14	0	.06	0	.07	.75	.83	0	.13	.1	0	.75
Warbling Vireo	.12	0	0	.04	.3	.5	.17	.1	.13	.1	.25	0
Chipping Sparrow	.11	0	.25	.08	.07	.25	0	.3	.13	.06	.13	0
Total Counts	81	14	16	26	15	4	6	10	8	51	8	4

*Numbers represent the frequency of occurrence of each species in total counts. These 24 species were the most frequent (> 10%) in the total counts.

+ f is frequency of occurrence in total counts (N=81).

Age of Plantings

From these data several generalizations can be drawn. Most of the species utilizing these plantings are found throughout the state. Except for Horned Larks, Bobolinks, and Savannah Sparrows, which are sometimes found in recently planted or young belts adjacent to their usual grassland habitat, most birds use belts over five years old. While older belts seem to support more breeding species in a given year, most species have been found in belts of varying ages. Raptors and hole-nesting species, as would be expected, seem to prefer older (over 40 years) belts and tree claims. Among the former are Red-tailed and Swainson's Hawks and Great Horned and Long-eared Owls. The hole-nesters include Common Flicker, Red-headed Woodpecker, Great Crested Flycatcher, and Starling.

Size of Plantings

The number of rows in the belt does not seem to influence birds as much as might be expected. Of those species occurring in over 20% of the belts, only Least Flycatcher, Gray Catbird, and Yellow Warbler have not been found in belts of less than four rows. On the other hand, larger belts seem to support more species at one time. The density of breeding birds (total pairs/shelterbelt) is significantly correlated with both age ($N=81$, $r=0.3$, $p=0.015$) and size (acres) ($N=81$, $r=0.73$, $p=0.0001$) of shelterbelts. The diversity (number of species) is also significantly correlated with age ($N=81$, $r=0.56$, $p=0.0001$) and size ($N=81$, $r=0.49$, $p=0.0001$).

Types of Use

During the breeding season, shelterbelts usually form woody islands in a sea of cropland. Not counting birds flying over or occasionally perching in the belt on the way by ("visitors"), breeding species may use the belt in one of five ways.

1. They may carry on most of their activities within the confines of the belt leaving only occasionally and for a short time. Black-billed Cuckoo, Least Flycatcher, House Wren, Gray Catbird, Yellow Warbler, Northern Oriole, and Clay-colored Sparrow generally behave in this way.

2. They may "sing" and nest in the belt and forage both in and out of the belt. This is the pattern of the Eastern and Western Kingbirds, Brown Thrasher, American Robin, Common Grackle, Common Yellowthroat, American Goldfinch, and Song Sparrow.

3. They may nest and "sing" in the belt but forage widely as the Mourning Dove does. The Mourning Dove is one of the most abundant birds in North Dakota shelterbelts. A nest with eggs has been recorded as late as September 5.

4. They may use the belt for singing, and forage both in and out of the belt, but usually nest in adjoining fields, as does the Vesper Sparrow.

5. They may regularly and often use the belt for singing but rarely for foraging or nesting. The Red-winged Blackbird and Western Meadowlark fall into this pattern.

The avian breeding community in tree claims most closely resembles that found in natural riverine forests. As multirow belts mature, providing crown cover and hollow trees, similar communities seem to be developing.

Habitat Partitioning

Grassland birds usually feed on the ground and sing during aerial flights (Horned Larks, Longspurs) or from low singing posts (Meadowlarks, Vesper and Savannah Sparrows). Where no singing posts are available such birds may not be found. Even the Lark Bunting seems to like to take off from a perch to begin its flight song.

The trees and shrubs of shelterbelts resemble a late successional stage of a lowland hardwood community in the north central states (Samson 1979). Perches for singing and also for hawking rise above the adjacent cropland or grassland. Trees also provide leaves for foliage gleaners. As the belt matures and a crown develops, more microhabitats become available. None of these microhabitats exist without the woody vegetation. Some affinities of the more frequent species illustrate that these habitats are well exploited by the avian community (Table 3).

Table 3.--Avian Affinities in Shelterbelts

Species	Food Habits	Foraging Behavior	Foraging Level	Singing Level	Nesting Level	Nesting Site
Brown Thrasher	Omnivore	Ground gleaning	Ground	Crown	Low	Shrub
Mourning Dove	Granivore	Ground gleaning	Ground	Crown to middle	Usually middle	Tree
Vesper Sparrow	Granivore	Ground gleaning	Ground	Crown	Ground	Grass or crop
Least Flycatcher	Insectivore	Sallying	Low to middle	Middle	Middle	Shrub
Eastern Kingbird	Insectivore	Sallying	High	--	High	Tree
Western Kingbird	Insectivore	Sallying	High	--	High	Tree
Black-billed Cuckoo	Insectivore	Foliage gleaning	Middle	Middle	Middle	Tree
Yellow Warbler	Insectivore	Foliage gleaning	Middle	High	Middle	Tree or shrub
American Goldfinch	Omnivore	Foliage gleaning	Middle	High	Middle	Tree
Gray Catbird	Insectivore	Foliage gleaning	Low	Middle	Low	Shrub
Clay-colored Sparrow	Granivore	Ground gleaning	Ground	Middle	Low	Shrub
American Robin	Omnivore	Ground gleaning	Ground	Crown	Middle	Tree

WINTER BIRDS

Probably due to their relatively small size, shelterbelts and tree claims seem to have little influence on winter birds. In 24 studies (8 areas) near Fargo no winter bird community was found, and only the English Sparrow was found both breeding and wintering in the same belt. Ring-necked Pheasant and Gray Partridge seek shelter in belts but forage widely; Great Horned and Short-eared Owls sometimes rest there, while Common Flicker, Downy Woodpecker, Black-capped Chickadee, Bohemian Waxwing, and Common Redpoll occasionally forage in the belts but are not resident in any one belt.

MANAGEMENT

Studies are being continued, particularly in western North Dakota. Further analyses of habitat variables and species preference are in progress. Currently, we have documented the fact that numerous bird species not typical of grassland and cropland will use tree plantings. Like Goldsmith (1976) we are concerned about the removal of trees from the Great Plains and encourage continued emphasis upon the beneficial environmental effects of tree plantings and the birds they attract.

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28. Seven-year-old single row shelterbelt - Chinese elm.
29. Seven-year-old two row shelterbelt - Chinese elm and green ash.
30. Twenty-seven-year-old mature multiple row shelterbelt.
31. Old "1915" willow tree claim single row shelterbelt.
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Appendix I. -- Scientific names for plants and animals referred to in the text.

Common Name	Scientific Name
Red-tailed Hawk	*Buteo jamaicensis*
Swainson's Hawk	*Buteo swainsoni*
Ring-necked Pheasant	*Phasianus colchicus*
Gray Partridge	*Perdix perdix*
Mourning Dove	*Zenaida macroura*
Black-billed Cuckoo	*Coccyzus erythropthalmus*
Great Horned Owl	*Bubo virginianus*
Long-eared Owl	*Asio otus*
Short-eared Owl	*Asio flammeus*
Common Flicker	*Colaptes auratus*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Hairy Woodpecker	*Picoides pubescens*
Eastern Kingbird	*Tyrannus tyrannus*
Western Kingbird	*Tyrannus verticalis*
Great Crested Flycatcher	*Myiarchus crinitus*
Least Flycatcher	*Empidonax minimus*
Horned Lark	*Eremophila alpestris*
Black-capped Chickadee	*Parus atricapillus*
House Wren	*Troglodytes aedon*
Gray Catbird	*Dumetella carolinensis*
Brown Thrasher	*Toxostoma rufum*
American Robin	*Turdus migratorius*
Bohemian Waxwing	*Bombycilla garrulus*
Starling	*Sturnus vulgaris*
Warbling Vireo	*Vireo gilvus*
Yellow Warbler	*Dendroica petechia*
Common Yellowthroat	*Geothlypis trichas*
English Sparrow	*Passer domesticus*
Bobolink	*Dolichonyx oryzivorus*
Western Meadowlark	*Sturnella neglecta*
Red-winged Blackbird	*Agelaius phoeniceus*
Northern Oriole	*Icterus galbula*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
Common Redpoll	*Carduelis flammea*
American Goldfinch	*Carduelis tristis*
Lark Bunting	*Calamospiza melanocorys*
Savannah Sparrow	*Passerculus sandwichensis*
Vesper Sparrow	*Pooecetes gramineus*
Chipping Sparrow	*Spizella passerina*
Clay-colored Sparrow	*Spizella pallida*
Song Sparrow	*Melospiza melodia*
Longspurs	*Calcarius* spp.
Boxelder	*Acer negundo*
Caragana	*Caragana* spp.
Hackberry	*Celtis occidentalis*
Cotoneaster	*Cotoneaster* spp.
Russian-olive	*Elaeagnus angustifolia*
Green Ash	*Fraxinus pennsylvanica*
Honeysuckle	*Lonicera* spp.
Cottonwood	*Populus deltoides*
	Prunus spp.

Appendix I. -- continued.

Common Name	Scientific Name
Plum	*Prunus* spp.
Golden Currant	*Ribes aureum*
Woods Rose	*Rosa woodsi*
Willow	*Salix* spp.
Buffalo-berry	*Shepherdia* spp.
Lilac	*Syringa* spp.
American Elm	*Ulmus americana*
Siberian Elm	*Ulmus pumila*

STRIP-MINE RECLAMATION AND BIRD HABITATS

James R. Karr

Associate Professor
Department of Ecology, Ethology, and Evolution
University of Illinois
Champaign, Illinois 61820

ABSTRACT

Societal perceptions of wildlife have changed rapidly in the last two decades as demonstrated by a recent proliferation of environmental legislation. The Surface Mining Control and Reclamation Act of 1977 (PL 95-87) is an example of that legislation which opens many new potentials for enhancement of wildlife populations. Effective use of the opportunities provided by that Act requires more effective integration of applied and theoretical ecology. A model of the determinants of avian community structure is reviewed and discussed in light of reclamation needs on strip-mine areas.

KEYWORDS: birds, habitat, reclamation, stripmines

Societal perceptions of wildlife have undergone a rapid evolution in the last 10 to 15 years. Recent concern for "nongame" wildlife is one example. This conference and the earlier regional and national conferences which preceded it (Smith 1975, DeGraaf 1978a,b, DeGraaf and Evans 1979) are excellent examples of the changing interests of society. (Recently Brocke (1979) has suggested, legitimately in my opinion, that the "game-nongame" dichotomy should be avoided. I am sympathetic with that argument and, thus, will refer to wildlife throughout this paper.) Examples of major legislative innovations that demonstrate the changing value systems of society include the National Environmental Policy Act, the Endangered Species Act, Water Quality Act Ammendments of 1972, the Clean Water Act of 1977, and the Surface Mining Control and Reclamation Act of 1977 (PL 95-87). The importance of all forms of wildlife is clear in the mandates of all this legislation.

must include information concerning effects on endangered species (Sec. 770.12c), develop a fish and wildlife plan (Sec. 780.16), and demonstrate the use of best technology currently available for both fish and wildlife (Sec. 816.97 and 817.97) and revegetation (Sec. 816.116 and 816.117). In short, the regulations require a comprehensive premining permit application procedure (set forth in Sec. 771.23) which recognizes the importance of fish and wildlife protection and enhancement. Clearly, the language of SMCRA creates opportunities which did not exist, perhaps were not even dreamed of, a decade ago.

In my view there are two major problems which limit the comprehensive use of that legislation for the betterment of wildlife. The first is concerned with societal-legislative matters. While not all biologists are happy with the breadth and depth of that act, it must be acknowledged that tremendous new potentials exist. It only remains for biologists (and society in a more general sense) to use the potential of the legislation. By functioning in that process in the earliest stages of policy development and interpretation of the law, biologists stand a better chance of strengthening the law from a wildlife perspective. In the end, progress made as a result of implementation of SMCRA will come as a result of integration of societal-legislative activities with the most up-to-date biological theory.

It is with that biological theory that I perceive the second major problem. In my opinion, much of the technical expertise which has been brought to bear on many wildlife problems in the last four decades is based on what might be called "seat-of-the-pants intuition". To a great extent that has been the best available in the context of the times. However, satisfactory progress for wildlife resources in the future requires a more rigorous approach with quantitative and experimental foundations.

A related problem is the lack of communication between resource managers and generators of ecological theory. Many theoreticians have looked down upon managers, perhaps because of a disdain for mission-oriented research. Conversely, managers have been reluctant to evaluate the merit of recent theoretical developments, perhaps because they are too "esoteric". These and other roadblocks to cooperation have slowed the integration of the contributions of both groups into a coherent theory able to address a wide variety of problems. Successful solution of many reclamation problems must involve bridging the gap between the theoretician and the applied ecologist.

INTEGRATION OF THEORY AND APPLICATION

A recent example of the value of such integration is the use of island biogeographic theory in design of nature preserves. Although blanket incorporation of that theory by managers could lead to major resource problems, testing of that theory in real-world problems has resulted in major improvements in the theory as well as better management policies (Faaborg 1979, Soule et al. 1979, Kushlan 1979). Another integrative contribution comes with the merger of theoretical community ecology and the study of habitat relations and requirements in birds (Gauthreaux 1978).

Before wildlife biologists can effectively capitalize on the potential of SMCRA (and other environmental legislation), integration of theory and practice must develop. Only in this way can clearly defined and articulated principles for wildlife enhancement be forthcoming. Further, those principles must be more than vague generalities such as "improving the habitat will benefit wildlife".

Use of the term habitat is an excellent example of the kind of intellectual carelessness that has inhibited the development of a sound predictive foundation to the restoration of damaged ecosystems (or the preservation of existing ones and

their component species). At least three major meanings are implicit in this volume.

1. Habitat = vegetation type. Thus, we might speak of a grassland or forest habitat.

2. Habitat = the living and nonliving surroundings of an organism (Smith 1974). This includes all the resources required by a species as well as the components of its environment that are not viewed (by it) as resources. Some researchers urge limiting use of habitat to the set of physical conditions which surround an organism (Kendeigh 1974). In this usage the aggregate of living and nonliving is the biotope of the European literature.

3. Habitat = specific horizontal (vegetation configuration) or vertical (twig angle, leaf density) components of habitat gradients. In terms of vegetation components this is more commonly referred to as microhabitat, and is analogous to the use of microclimate of plant ecologists.

Commonly, although not always, biologists understand each other despite less than precise usage. However, how can we expect planners, engineers, and lay-persons to comprehend subtle differences in what we mean when we use a word in three slightly different ways in a single paragraph? Some might argue that this is a reentry into the terminology abyss which dominated the science of ecology three decades ago. However, communication is a major key to success. Since we must communicate efficiently and accurately to nonbiologists, I am not convinced that this terminological problem is a red herring. Attainment of our objectives in the wildlife field depend more than we admit on the clarity of our communication with the rest of the world, as well as among ourselves.

BIRDS AND HABITAT

During the past two decades there has been a rapid proliferation of studies examining the use of habitat and habitat selection in birds. These efforts have included studies of from one to many species. Paralleling these efforts have been an even greater number of studies examining community structure in terrestrial birds. I have recently completed an extensive review of the literature relating habitat use and community structure in birds (Karr 1980). From that review I have developed a general model showing the primary variables (and their interactions) which govern avian community structure. There is neither time nor space here to allow a detailed presentation of that review. However, it may be useful to review briefly the general results of that effort (Fig. 1), as well as to evaluate the relevance of consideration of each of the variables in reclamation of strip-mined lands.

Literally hundreds of studies in the past decade have demonstrated a plethora of special circumstances which modify the relationships between birds and their habitats. For single species or entire communities a bewildering array of variables is relevant to different extents among habitats and geographic areas. This synopsis is meant to extract general principles of use in the planning of mining activities for enhancement of bird populations. In this discussion I will outline some of those principles to demonstrate their relevance to habitat use by a single species and/or to overall community structure. Documentation of the assertions in this synopsis is available in Karr (1980).

History

Both long- and short-term historical factors, such as dynamics of climate cycles, are of major significance to the evolution of avian communities. In addition, a wide array of biogeographic conditions such as geographic extent of habitat islands and their distances as well as the nature of intervening dispersal barriers must also be considered. Finally, occupation of trophic roles by other taxa may be important as regulators of avian evolution.

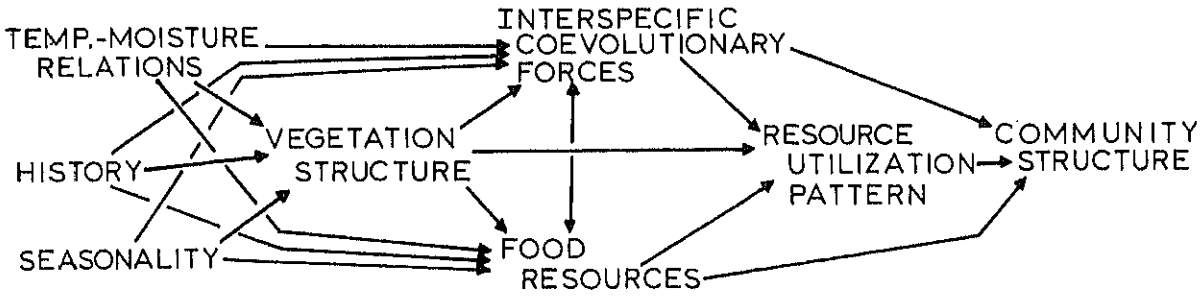

Figure 1.--Conceptual model showing the primary variables (and their interactions) which govern the development of avian community structure. (From Karr 1980)

Temperature-Moisture Relations

Moisture and temperature relations affect weather-dependent foraging, bird size and energetics relationships, and breeding periodicity. At community levels the number of species and their abundances change from dry to mesic sites in a wide variety of major vegetation types.

Seasonality

Both the amplitude of environmental fluctuations and their predictability are of special significance to organisms. The importance of seasonal rhythms in determining timing of breeding and migration have been well documented. The concept of "lean season" in annual cycles and "bottlenecks" over longer periods have major evolutionary consequences to avian communities. As noted below, seasonality is also linked to food resource complexity and abundance and, therefore, trophic structure of the community.

Vegetation Structure

The most extensively documented determinant of avian community structure is vegetation structure. Studies of the relationships between vegetation structure and community diversity in birds were pioneered by R. H. MacArthur (MacArthur and MacArthur 1961). He demonstrated that bird community diversity increases with increasing complexity of vegetation. Later, this relationship was demonstrated by many researchers on a wide array of organisms. Regrettably, two problems have arisen. First, the documentation of a correlation does not really explain the cause. It is a general, first-order approximation to a very complex interaction of numerous vegetation and vegetation-related variables. It thus must be explored in more detail to account for the myriad of factors as they vary from place to place in their influence on community structure. The weakness of the general correlation in many circumstances

leads to the second problem. Many researchers have devoted inordinate time to finding exceptions to the general pattern of vegetation-avian community correlations. The end point is often the damning of the relationship rather than pursuit of the causes of the breakdown with the potential for major expansion of the theory.

The principle elucidated by MacArthur, habitats of high complexity support more diverse biotas than those of low complexity, is simple although it is often overlooked by individuals anxious to disprove a more specific statement of the general principle.

As several researchers have shown, a number of measures of complexity (e.g., plant species diversity, physiognomic diversity, horizontal and vertical heterogeneity, and foliage volume) may be used to restate the principle, depending on local circumstances. For birds in areas of homogeneous vegetation structure, the most important habitat variables which can be conviently measured are the density of vegetation in three layers (herb, shrub, and tree). However, that homogeneous ideal almost never exists, with the result that the single-solution explanation (foliage height diversity) is inadequate. Many secondary variables are also important.

Secondary variables of special significance in strip-mined areas are topographic complexity and presence of water (Karr 1968). Other secondary variables of significance include many components of the other primary variables in Fig. 1. Success in management efforts depends upon clarification of many of these second-order interactions.

Interspecific Forces

The importance of competition as a force molding the use of habitats by birds has also been the subject of especially extensive research efforts although some well-deserved challenges of the primacy of competition are appearing. Clearly, competition as well as predation and other coevolutionary interactions (pollination and seed dispersal) affects the use of habitat by individual species and, in the aggregate, multispecies communities.

Food Resources

The type and quantity of food resources, as well as the spatial and temporal distribution of those resources, play a major role in determining avian community structure. These patterns affect timing of movements (migration, nomadism, etc.) and breeding and molt cycles. Guild additions over a successional gradient and changes in community complexity on latitudinal gradients reflect, at least in part, the role of food resources in governing community structure. Limited availability of specific food resources may limit the survival of certain guilds or species and affect the development of niche-width and overlap patterns and the generalist vs. specialist strategies of species in a community.

Food resources play a pivotal role in linking the interactions of many of the primary variables in Figure 1, especially the vegetation structure-community structure linkage. The spatial and temporal distribution of resources is, to a great extent, determined by seasonality. In addition, the presence of a structural complexity involved in vegetation creates substrates for feeding and concealment of arthropods which can be exploited by birds. Further, the development of vegetation with fruiting and flowering strategies is a consequence of the architecture of the plants as well as the coevolutionary pressure between the plants and their pollinators/dispersors.

Resource Utilization Patterns

Food resource distribution and abundance, physical environment, vegetation structure, and coevolutionary pressures [illegible]

esource

utilization patterns of species and the complex communities they form.

With this very brief sketch I will now explore how this model (Fig. 1) can be used to contribute to the emerging discipline involved with recovery and restoration of damaged ecosystems.

BIRDS, HABITATS, AND STRIP MINES

The challenge for the future is to use this background of understanding in the effort to enhance bird populations on strip-mined land. To what extent does strip mining modify any of the primary variables just discussed? Further, what management programs can be implemented to minimize those negative influences or to speed the recovery process?

The primary influences of the historical factors discussed above relate to the principles of island biogeography. The size of a patch of habitat has clear effects on the number of species to be found as well as on the trophic structure of the biota. Small islands, for example, are less likely to support many specialist species, large species, and species which feed at higher trophic levels (Wilson and Willis 1975). This knowledge is invaluable in planning for wildlife enhancement. As in other uses of SMCRA, the importance of preoperational planning is demonstrated.

Recent research in mined areas in eastern North America has shown the importance of islands created by strip-mine activities. In both Tennessee (Allaire 1978a) and West Virginia (Whitmore and Hall 1978), creation of islands of grassland on reclaimed strip mines has resulted in the expansion of grassland species into new areas.

If cautiously used, the theory of island biogeography can be used to determine the minimum size of a specific habitat which will insure perpetuation of a desired biota. In addition, it can be useful in evaluating the potential value of unique, rare, or uncommon habitats within the region (Graber and Graber 1976).

Another significant lesson to be learned from the theory relates to probabilities of colonization. Mining of extensive areas can reduce the chances of colonization because of a lack of seed sources for plants. This can be offset to a certain extent by seeding and planting of desirable species. However, that will not result in a truly diverse community typical of natural areas. Thus, preservation of remnants of the full community in extensive mined areas can serve to speed reclamation and, in addition, to make the developing commuinty more attractive. For animals, and especially vertebrates, this is exceedingly important for the less mobile forms such as mammals, reptiles, and amphibians which are very difficult to establish with release programs. The significance of this fact should not be overlooked even for the more mobile groups like birds and insects. Since mining activities may affect animal populations on nearby sites (Allaire 1978b), buffer strips may be required to protect remnants or otherwise fragile areas near mining activities.

Abiotic factors such as temperature and rainfall patterns are generally not subject to control following mining. However, success of wildlife enhancement programs is strongly dependent on these patterns. For example, the abiotic problems to be addressed in the arid west, the humid east, or the special problems of the topographically complex areas of West Virginia are markedly different.

Other abiotic factors can be affected and are especially important in determining the colonization potential for plants. These include surface soil chemistry, texture, and composition as well as topography. Further, it is possible to control certain microclimate characteristics with careful reclamation efforts. Much of the technology for this abiotic reclamation is known (Grim and Hill 1974). Unfortunately, the

pattern of topographic complexity, land-water interspersion, and spatial mosaic of vegetation types for wildlife enhancement cannot be specified. At this point the general vegetation type required by many bird species is known, but quantification of those relationships so that specific reclamation models can be constructed is still in the future.[1]

Perhaps the most important abiotic consideration in strip mining is the need to isolate strata which may degrade water or land quality (Grim and Hill 1974, Hill and Grim 1977) as so often happens with acid-mine drainage.

After making provisions for the best soil substrate along with topography, drainage, and related matters, the reclamation specialist must ensure that a suitable array of plants will colonize the area. As noted above, this may be done through natural colonization or with plantings. A major problem in reclamation is that mature communities are often the major objective but they can be attained often only after many years, even decades, of careful land management (Riley 1977). It is thus very important to plan for optimization of a variety of societal benefits in the short term which are compatible with the needs for enhancement of the longer-term objectives. A careful balance must be struck here between short- and long-term goals. Provision for quick establishment of cover must provide for early successional viability as well as ensure a smooth transition to the desired later successional stages on the site.

Careful planning to ensure the redevelopment of a natural complex of vegetation should result in establishment of most of the vegetation-related requisites for the birds. These include an array of food resources (e.g., seeds, fruits, and insects) as well as appropriate nest sites and song perches. Care should be taken to ensure that these requisites are all provided. Early reclamation efforts in east-central Illinois often produced depauperate avifaunas due to plantings of homogeneous stands of species such as black locust. Modern efforts should avoid this problem by emphasizing an array of species representative of the local flora.

One of the most important components for a plan to enhance wildlife populations is the careful selection of the desired complex of wildlife species. Obviously, this must be done in the context of the overall land-use objectives for the mined area as well as for surrounding areas. This may include many different objectives such as forestry, agricultural crops, grazing, and urban land use. Each of these alternatives dictates the proportion of the land to be reclaimed for wildlife purposes and some of he constraints on that development. If planning for wildlife enhancement is to be ffective, it must be done in parallel with all other planning efforts. Wildlife iologists cannot be expected to do the most effective job if they are not involved in early planning efforts.

Once land-use decisions are made, wildlife biologists will have a clear idea of the area of land to be used and how it may be interdigitated with other land uses. Decisions about post mining land use will reduce the number of options available as objectives in wildlife enhancement. Additional decisions must then be made by biologists in consultation with the ultimate users of the land, as well as with society in a broader sense. This may be accomplished directly or indirectly through established legislative requirements (e.g., return land to premining uses).

It is important to recognize that there often will not be a best vegetation type or stage as a general reclamation objective. Local needs or other special circumstances may dictate this decision. Similarly, there is no inherent merit to reclamation procedures designed to yield the most diverse avifauna. High diversity may be

[1]Samuel, David E. and Robert C. Whitmore. Reclamation and management of surface mined areas for game and nongame birds in West Virginia. Paper presented to Hill Land Symposium, October 3-5, 1976, Morgantown, West Virginia.

the goal in one area, while specific species or groups of species may be the management targets in other circumstances.

After the final selection of major enhancement objectives, a detailed survey of the requirements of the desired species should be compiled. This can be used to outline the details of the reclamation plan over both the short and long term. Great care should be taken throughout this effort because even minor errors and oversights may be difficult or impossible to correct for many decades.

Whenever possible, this should include assessment of evolutionary fitness rather than just presence over a range of species and habitats. This has rarely been done although it is clearly an important consideration. Some species have been shown to have lower reproductive success on mined areas than in natural habitats (Wray et al. 1978).

One final and very important point must be made. It is essential that highly trained, professional biologists be involved throughout this process, from the earliest plans to the details of management of reclaimed land. This must be done to avoid reclamation short-cuts which negate the plans of the best biologist. Further, not all plans will be perfect and errors might be corrected quickly if biologists are present to recognize and correct inadequacies and oversights in the original plan.

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BRUSHLAND/STEPPE BIRD POPULATIONS

R. Roy Johnson, Lois T. Haight, National Park Service, School of Renewable Natural Resources, University of Arizona; Meribeth M. Riffey, Department of Biology, Western Washington University, Bellingham; and James M. Simpson Associate, Department of Biology, Museum of Northern Arizona, Flagstaff

ABSTRACT

The varied physical and climatic characteristics of the western United States support a plethora of vegetation types. Most of these vegetation types are some form of brushland or arid grassland due, in part, to arid conditions and shallow soils. The avifaunas of upland brushland/steppe types are often relatively poor. However, many birds are largely or entirely dependent on these vegetation zones. By contrast wetlands associated with these types support some of the richest avifaunas on the entire North American continent.

KEYWORDS: nongame birds, brushland, scrubland, desert, riparian, grazing regions, vegetation classification, rangeland.

INTRODUCTION

When the western United States was first settled in the mid- to late 1800s the early inhabitants found a vast variety of vegetation types. Altitudes from below sea level to more than 14,000 ft., combined with a variety of climatic, soil, terrain and other characteristics, resulted in almost all conceivable situations from the most arid of Death Valley deserts to Olympic rain forests. The vastness of grassland and brushland types led to these western states being known as the "range states." The ratio of people to resources was very favorable at first, with open range "yours for the taking." Hunting and trapping was a way of life, not only to protect livestock from predators but also to provide furs for trade and clothing as well as meat for the table. Small coffer dams, brush and earthen dams and hand-dug ditches provided water for small family farms and livestock.

Western coniferous forests were still not in great demand since eastern forests provided a plentiful supply of both hardwood and softwood lumber. In addition to being large distances from the growing eastern cities where building supplies were in greatest demand, rugged terrain and shortage of men and equipment for harvesting trees presented problems. Even the cutting of the giant sequoias and redwoods was difficult. So many of these giants shattered as they fell from great heights that special techniques had to be developed to enable their cutting to be commercially successful.

However, the impact of the grazing industry on brushland and arid grasslands was a very different story. Ever larger numbers of livestock crowded onto the ranges in order to provide an adequate supply of meat for the growing eastern cities. As time progressed into the 1900s cattle continued to be grown on ranges not only for the expanding eastern population but for (in many cases) even larger western cities. Livestock and wildlife competed for decreasing amounts of food, often resulting in badly overgrazed rangeland--degraded through erosion, compaction and reduced forage production.

Only during the last few decades have concerned individuals and resource management agencies initiated the necessary steps to correct some of these problems. Much has yet to be accomplished. Concepts of sustained yield and multiple use have developed, with increasing demands from various user groups. For example, one of the fastest growing activities in the United States is recreation. Shorter workweeks and greater access to forests and rangelands have led to an increase in nonconsumptive uses, such as backpacking, camping, skiing and birdwatching. Contrastingly, hunting and fishing have not grown at comparable rates. In fact, active antihunting movements have developed throughout the country. Still, resource management agencies commonly emphasize game management instead of true wildlife management in spite of Leopold's (1933) stressing the pitfalls of this practice almost 50 years ago (Carothers and Johnson 1975; Talbot 1975). This results in an undue amount of activity for approximately 10% of the public, while placing too little emphasis on providing suitable recreational activities for the other 90% of the population. The useful roles that nongame birds play in insect control and other beneficial activities have been long understood. However, their value to this large segment of the taxpaying user has, until recently, been largely ignored. This paper will discuss the great diversity and importance of brushland/steppe types to nongame birds and thus to this large segment of recreationists. In addition to the fact that hunting is engaged in by so few persons, the percentage of game birds is extremely small when compared to nongame species. Since the findings and syntheses in this paper are ecologically derived and the terms "game" and "nongame" are sociological rather than ecological no attempt has been made to separate game from nongame birds in population figures, tables, etc.

HABITAT CLASSIFICATION

The western United States has been classified in innumerable ways by various authorities during the past 90 years. These schemes have included ecological patterns, range and forest classification, and, more recently, land use patterns. One of the first ecological systems was Merriam's (1890) Life Zones. In spite of criticisms regarding its simplistic approach, this system has been widely used by vertebrate zoologists and systematic botanists, especially in the Southwest. Dice's (1943) Biotic Provinces were widely used from the 1940s through the 1960s and a similar classification, Bailey's (1978) Ecoregions, is now widely used. Standardized rangeland classifications include "Natural Vegetation of the Range States" and the 18 grazing types recognized by the Interagency Committee, as treated by Stoddart and Smith (1955).

Vegetation classification and mapping have developed as closely allied disciplines to ecosystem classification. The two basic methods of vegetation classification are floristic and structural. Although most classification systems use a combination of the two methods, Fosberg (1961) has developed a thorough structural classification for world-wide vegetation.

In addition to structural versus floristic systems one may differentiate between hierarchical and classless systems. Classless vegetation types are widely and simply developed (see Kuchler 1964) by using a noun with modifiers (e.g., California Steppe) which do not necessarily imply a systematic relation to surrounding vegetation.

Although hierarchical classification is complicated to develop, it has the advantage of conveying a systematic relationship among the various vegetation types within the system in the same sense plant and animal systematics show phylogenetic relationships among living organisms. For purposes of our discussion here we will rely heavily on Stoddart and Smith's (1955) rangeland classification, and Brown et al. (1979; Table 1) vegetation classification which, in addition to being heirarchical, is also digitized for ready computer storage and retrieval. Vegetation classification and mapping, in relationship to wildlife values, has benefited greatly from recently developed remote sensing techniques (Mouat and Johnson 1978). Brown et al. (1979) also presents a short bibliography of vegetation classification systems, for those interested in further references.

TABLE 1. A list of vegetation types that are entirely or largely brushland/steppe types (courtesy Brown et al. 1979) in the western United States.

UPLAND TYPES

131 Arctic-Boreal Scrublands
- 131.5 Rocky Mountain Alpine and Subalpine Scrub
- 131.6 Sierran-Cascade Alpine and Subalpine Scrub

132 Cold Temperate Scrublands
- 132.1 Great Basin Montane Scrub
- 132.2 Sierran-Cascade Montane Scrub
- 132.3 Plains Deciduous Scrub

133 Warm Temperate Scrublands
- 133.1 Californian Chaparral
- 133.2 Californian Coastalscrub
- 133.3 Interior Chaparral

141 Arctic-Boreal Grasslands
- 141.4 Rocky Mountain Alpine and Subalpine Grassland
- 141.5 Sierran-Cascade Alpine and Subalpine Grassland

142 Cold Temperate Grasslands
- 142.1 Plains Grassland
- 142.15 Scrub-Grass Disclimax Series
- 142.2 Great Basin Shrub-Grassland

143 Warm Temperate Grasslands
- 143.1 Scrub-Grassland (Semidesert Grassland)

152 Cold Temperate Desertlands
- 152.1 Great Basin Desertscrub

153 Warm Temperate Desertlands
- 153.1 Mohave Desertscrub
- 153.2 Chihuahuan Desertscrub

154 Tropical-Subtropical Desertlands
- 154.1 Sonoran Desertscrub

WETLAND TYPES

*222 Cold Temperate Swamp and Riparian Forests
- *222.2 Plains and Great Basin Riparian Deciduous Forest
  - *e.g., 222.21 Cottonwood-Willow Series
- *222.3 Rocky Mountain Riparian Deciduous Forest
- *222.4 Sierran-Cascade Riparian Deciduous Forest

*223 Warm Temperate Swamp and Riparian Forests
- *223.2 Interior Southwestern Riparian Deciduous Forest and Woodland
  - *e.g., 223.22 Mixed Broadleaf Series
- *223.3 California Riparian Deciduous Forest and Woodland

224 Tropical-Subtropical Swamp, Riparian and Oasis Forests
- *224.5 Sonoran Riparian and Oasis Forest
- *224.51 Palm Series
- *224.52 Mesquite Series
- *224.53 Cottonwood-Willow Series

TABLE 1. Continued

231 Arctic-Boreal Swampscrubs
- 231.6 Rocky Mountain Alpine and Subalpine Swamp and Riparian Scrub
- 231.7 Sierran-Cascade Alpine and Subalpine Swamp and Riparian Scrub
  - e.g., 231.71 Willow Series

232 Cold Temperate Swamp and Riparian Scrubs
- 232.2 Plains and Great Basin Swamp and Riparian Scrub
- 232.3 Rocky Mountain Riparian Scrub
- 232.4 Sierran-Cascade Riparian Scrub
- 232.5 Pacific Coastal (Oregonian) Swamp and Riparian Scrub

233 Warm Temperate Swamp and Riparian Scrubs
- 233.2 Interior Southwestern Swamp and Riparian Scrub
  - e.g., 233.21 Mixed Narrowleaf Series
    - e.g., 233.211 *Cephalanthus occidentalis-Baccharis glutinosa*-mixed scrub Association
- 233.3 California Deciduous Swamp and Riparian Scrub

234 Tropical-Subtropical Swamp and Riparian Scrub
- 234.7 Sonoran Deciduous Swamp and Riparian Scrub
  - 234.71 Mixed Scrub Series
    - e.g., 234.711 *Prosopis pubescens Prosopis juliflora torreyana-Pluchea sericea* Association
  - 234.72 Saltcedar Disclimax Series
    - e.g., 234.721 *Tamarix chinensis* Association 1/

*242 Cold Temperate Marshlands
- *242.5 Great Basin Interior Marshland

*243 Warm Temperate Marshlands
- *243.3 Chihauhaun Interior Marshland
- *243.4 Mohavian Interior Marshland
- *243.6 Californian Interior Marshland

*244 Tropical-Subtropical Marshland
- *244.7 Sonoran Interior Marshland

250 Strand Formation 2/

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*Denotes types which were included because of their close association with an upland brushland/steppe type although, technically, they themselves are not brushland/steppe types (e.g., Cottonwood-Willow Series).

1/"Reclamation Disclimax" of Johnson (1979)

2/Strandland is the wetland equivalent of desertland and is defined by Brown et al. (1979) as "Beach and river channel communities subject to infrequent but periodic submersion, wind-driven waves and/or spray. Plants are separated by significant areas devoid of perennial vegetation."

BRUSHLAND AND STEPPE

Brushland is a common term used to designate a number of shrub or scrubland types, and the three terms will be used herein synonymously. Although steppe is a more technical term than brushland, its definition is certainly not standardized. Dictionaries and geography references usually refer to arid grass-covered plains, commonly restricting this to Eurasia and, thereby, denoting it as a localized, not a worldwide, vegetation type. This has resulted in many vegetation systems for North America which do not use the term. We will use it here to denote a grassland type intermediate between the closed grasslands of the Great Plains and the sparse grasses of the western "desert grasslands." Fosberg (1961) defines steppe as "open grass or other herbaceous vegetation, the plants or tufts discrete but averaging not over twice their diameters apart." By contrast, desert vegetation is defined by Fosberg (1961) as "...plants so widely spaced, or sparse, that enough of the substratum shows through to give the dominant tone to the landscape; for pratical purposes, where the plants are separated from each other by more than twice their diameter on the average." Combinations of scrub and these open grass types are called by structural terms such as "steppe scrub", or combinations of floristics and structure such as "oak grassland."

Brushland and arid grasslands cover a large percentage of the western United States. They occur from below sea level as tropical-subtropical (warm desert) types through cold deserts (Arctic-Boreal) at higher elevations and latitudes. While not emphasizing their importance as nongame habitat and recreational lands, Byerly (1979) summarizes the extent and values of these areas, in part. The two broad habitat types we are discussing include four of Stoddart and Smith's (1955) nine major range types (and portions of some of the others). Of the 18 grazing types established by an Interagency Committee, nine are brush or arid grasslands and parts of some of the remaining nine types would be appropriate. In addition, a large number of Brown et al. (1979) upland types must be included (Table 1). We must also include a large number of wetland types representing the most important wildlife habitats in the western United States and, in many cases, in all of nontropical North America. These western wetland types are often associated with riparian forests and woodlands which, for example, support the largest densities of noncolonial nesting birds in the United States and among the higher populations for the world (Carothers et al. 1974; Johnson 1971 and 1979).

WILDLIFE AND RECREATIONAL VALUES

We have thus far established that western brushlands and arid grasslands are represented by several major vegetation types which, in turn, are important elements in a variety of diverse ecosystems. When considering wildlife values for a given habitat type several factors must be evaluated. We have already mentioned three, (a) floristics, or species present, (b) structure, and (c) whether they are upland or wetland types. Most classification and mapping schemes take into account obvious structural differences, such as trees versus shrubs, or evergreen versus deciduous plants. However, a factor of great importance to wildlife is cover as related to plant spacing. Thus, the wildlife values of a brushland or grassland vary tremendously based on closed versus open or sparse cover. Carothers and Johnson (1971), for example, found a straight-line relationship between the number of mature trees per acre and the number of nesting birds per unit area along rivers in central Arizona. Thus, in order to evaluate a mature riparian forest, at least three factors are important: (a) species of trees, (b) size (forage layers present = Foliage Height Diversity), and (c) spacing. In addition, the adjacent habitat influences the species composition and population densities of riparian birds (Carothers et al. 1974) and, more recently, investigations along streams in southern Arizona have shown the reciprocal is true. Carothers (unpublished ms.) found that even in upland vegetation bird population densities increase in the proximity of a stream.

NONGAME BIRD HABITAT TYPES

Although the major habitat types covered by this paper have been listed (Table 1), we shall here discuss some of them briefly. Several state floras include brief descriptions of major vegetation types; e.g. Kearney and Peebles (1969) for Arizona, Munz and Keck (1959) for California and Correll and Johnston (1970) for Texas. Lowe and Brown (1973) have recently published, separately, a summary of Arizona's vegetation types. Most other Western states are treated by similar publications. Table 2 lists several habitat types along with a rough idea of bird species numbers and population densities which one may expect to find in those types. Most of the types listed are upland types with only a scattering of riparian wetland types for comparison since other papers in this symposium address riparian habitat. An important point to consider, (Table 2) is that the basic structure of riparian habitat usually differs greatly from the surrounding upland habitat in the types under discussion (e.g., Cottonwood-Willow Forest in a Creosotebush Desert).

TABLE 2. Breeding Birds densities for various habitats. These are crude figures for areas which, in most cases, have not been overgrazed, affected by urban development or otherwise mistreated. For more specific information refer to Johnson et al. (1977) and Johnson (1979).

Upland Vegetation Types	Species Present[1/]	Population Densities[2/]
Tundra (steppe)	3 or 4	15 - 20
Saltbush	3 or 4	15 - 20
Creosotebush	3 or 4	15 - 20
Grassland (Desert to Prairie)[3/]	5 ±	25 - 100
Sagebrush (Northern Desert Shrub)[3/]	10 - 12	50 - 100
Palo Verde-Bursage (Southern Desert Shrub)	10 - 12	50 - 100
Chaparral	10 - 15	50 - 100
Pinyon-juniper	20 ±	40 - 80
Ponderosa Pine Forest	20 ±	200 - 350
Boreal Forest (Mixed Conifer)	20 ±	200 - 350
Riparian Vegetation types		
Southwest Mixed Deciduous Forest	25 - 30	300 - 400
Sycamore-Coast Live Oak	25 - 30	300 - 600
Mesquite Woodland	10 ±	400 - 600
Cottonwood-Willow	25 ±	600 - 1,300
Urban (Artificial Riparian) (Emlen 1974)[4/]	15	615
Desert Comparison Plot[5/]	21	23

1/Species expected on 10-15 acre plot.
2/Pairs/100 acres or 40 hectares.
3/Information also used from Riffey's unpublished studies for Bureau of Land Management in Northwest Arizona.
4/This was compared to a desert plot (5/) presumed to be similar to the urban area before its settlement. In Condor 76:184-197.
5/See 4/.

Alpine Tundra

This high, cold desert type commonly supports grasses and forbes, with shrubs, especially willow (Salix spp.) along streams. Although precipitation may be well in excess of 20 inches per year, most of it is in the form of snow or ice. A short growing season (with water in the form of ice and, thus, unavailable to plants) results in this arid habitat. Typical breeding birds are Water Pipits, Horned Larks and Rosy Finches. [1/]

1/Scientific names of birds referred to in the text are shown in Appendix I.

Arctic-Boreal Scrublands

Like the previous type, this covers a relatively small part of the contiguous western United States, but occurs over larger areas of Alaska and northern Canada. Willows occur in moist areas away from streams and dwarfed, shruby conifers, e.g., Bristlecone pines (Pinus aristata) occur in some areas. These two coldest types have shallow, easily disturbed soils and innumerable studies have demonstrated their inability to resist more than light impact from recreationists and grazing. Although bird species and numbers are few, the importance of these two coldest types as wildlife habitat and recreation probably far exceed their value as rangeland. Some mammals, e.g., marmots (Marmota spp.) and pikas (Ochotona princeps), are highly dependent on these habitats.

Cold Temperate Scrublands

This includes the often-called mountain shrub, or mountain brush types (Great Basin Montane Scrub, Sierran-Cascade Montane Scrub, and Plains Deciduous Scrub) which commonly consist of a large percentage of deciduous shrubs such as Gambel oak (Quercus gambelii), maples (Acer spp.), mountain mahoganys (Cercocarpus spp.) and sumacs (Rhus spp.), with some manzanitas (Arctostaphylos spp.) and evergreen scrub oaks (Quercus spp.). These types generally occur in mountainous or hilly terrain at elevations lower than coniferous forests or oak woodland at the same latitude. They generally receive moderate precipitation both as rain and snow, with moderate evaporation rates and medium to short growing seasons. Typical birds are Scrub Jays, Bushtits, Rufous-sided Towhees, Blue-gray Gnatcatchers, and Black-throated Gray Warblers.

Warm Temperate Scrublands
(California Chaparral, California Coastalscrub, and Interior Chaparral)

This is a mixed group of evergreen sclerophylls ("true" chaparral) and "soft chaparral" or evergreen nonsclerophylls. Major shrub species in the true chaparral include manzanitas, scrub oaks, mountain mahoganys, silktassels (Garrya spp.), species in the buckbrush family, Rhamnaceae, (Ceanothus and Rhamnus) and, in California, chamise (Adenostoma fasciculatum). These usually occur at elevations below coniferous forests. The soft chaparral, or coastalscrub usually occurs just below the California Chaparral and is composed largely of sagebrush (Artemisia spp.) and sage (Salvia spp.). These plants grow in areas of limited water availability. This may be due to shallow gravelly soils, winter rains when evaporation is low but other growing conditions are not optimum, or in areas of summer rains when evaporation is high. These areas receive moderate amounts of precipitation, nearly all as rain.

Typical birds are basically the same as those for cold temperate scrublands, excluding Black-throated Gray Warblers and adding the Wrentit which typifies the California Chaparral.

Arid Grasslands
(Steppe, Shrub-Grass Disclimax, Shrub Grassland and Semidesert Grassland)

Arid grasslands are those whose plants are generally separated by half their diameter or more and usually are composed of short grasses. Typical Shortgrass Prairie types are excluded since they often consist of a closed cover, even though short. Typical species include: several gramas, e.g., black grama (Bouteloua eriopoda), blue grama (B. gracilis) and side-oats grama (B. curtipendula); Hilaria

spp., e.g. curly mesquite (H. belangeri), tobosa (H. mutica), and big galleta (H. rigida); Muhlenbergia, e.g. bush muhly (M. porteri) and numerous other three awns (Aristida spp.), bromes (Bromus spp.), etc. Many species of introduced, weedy (usually annual) grasses have become established, especially on overgrazed ranges. These include wild oats (Avena fatua), Schismusspp., annual bluegrass (Poa annua), and lovegrasses (Eragrostis spp.).

Arid grasslands receive from 10 to 15 inches of precipitation annually, therefore excluding the Great Plains types and montane meadows (USDA 1941). These grasslands generally occur at lower to intermediate elevations and are often intermixed with scrublands or desertlands. One exception is the high elevation Artic-Boreal Grasslands, covered under Artic-Alpine types discussed earlier. Other papers in the symposium address grassland management and mountain meadows while papers such as Wiens and Dyer (1975), in earlier symposia of this series, address Short Grasslands.

Many of the current brushlands were formerly grasslands or mixed shrub and grasslands, according to numerous old reports, diaries, and other records. Photographic studies, such as Hastings and Turner's "The Changing Mile" (1965), have documented this fact. Considerable disagreement exists regarding the cause(s) of these changes, but the most widely accepted are overgrazing and climatic shifts. Evidence for overgrazing can be drawn from recent U.S. Forest Service experiments which have converted brushlands to grasslands. These projects have been conducted in Chaparral, Northern Desert Shrub, and Southern Desert Shrub (personal observation). Because of the vast geographic and altitudinal ranges of arid grasslands, it is difficult to generalize regarding climatic and edaphic conditions in which they occur. The conditions we have listed for the scrub types occurring near a particular grassland provide this information. Grasslands are commonly among the most depauperate vegetation types in regards to numbers of breeding avian species and are not much better in regards to population densities (Table 2 and Wiens and Dyer 1975). Breeding grassland birds include Golden Eagles, Burrowing Owls (Collins 1979; Johnson et al. 1979), Scaled Quail, White-necked Ravens, Horned Larks, Eastern and Western Meadowlarks, and numerous Fringillids such as Cassin's and Rufous-Crowned Sparrows. Probably of equal or even greater benefit than breeding habitat for nongame birds is the value of southern grasslands as wintering grounds for granivores, such as huge flocks of numerous species of the family Fringillidae (finches, sparrows and longspurs).

Cold Temperate Desertlands
(Great Basin Desertscrub)

Several shrub species dominate this northern desert type, including sagebrushes (Artemisia ramosissima), rabbitbrush (Chrysothamnus spp.), Mormon tea (Ephedra), and others. The Great Basin Desert occurs in low areas between the Rocky Mountains to the east and Sierra-Cascades to the west. Low precipitation (much as snow), cold winters, and dry, hot summers confine vegetational growth to a brief spring period. Poor drainage in this intermontane region results in salt marshes and alkaline flats. Bird species diversity and population densities are low both in summer and winter. Common breeding species are the Sage Thrasher, Sage Sparrow and Brewer's Sparrow.

Warm Temperate Desertlands
(Mohave Desertscrub and Chihauhaun Desertscrub)

These deserts are further south and warmer than the Great Basin Desert. However, elevations in general are higher than those in the Sonoran Desert. The Sonoran Desert, another southern desert, is not included here for it has a direct geographic-ecological connection with the thornscrub types of western Mexico which adds greatly

to its floral and faunal richness (see discussion of Sonoran Desertscrub under Tropical-Subtropical Desertlands). More tall shrubs occur in the Mohave and Chihuahuan Deserts, especially the latter, than in the Great Basin Desert. However, no upland trees exist in the Mohave Desert with the exception of the larger Joshua-trees (Yucca brevifolia). In the Chihuahuan Desert, a few species of large yuccas are also found, such as the giant-dagger (Yucca carnerosana). Large arroyos in both deserts support shrubs which, under ideal conditions, may grow into trees. In the Chihuahuan Desert, these include mesquites (Prosopis spp.), desert-willow (Chilopsis linearis) and several acacias (Acacia spp.). Fewer species attain tree size in the Mohave Desert: these including mesquites (Prosopis spp.) and crucifixion-thorn (Canotia holacantha). Endemic shrubs of the Mohave Desert include Parry saltbush (Atriplex parryi), Mohave sage (Salvia mohavensis), and Death Valley sage (S. funerea) (Benson and Darrow 1954). Torrey yucca (Yucca Torreyi), lechuguilla (Agave lechuguilla), tarbush (Flourensia cernua), and sandpaper bush (Mortonia scabrella) are among the typical shrubs of the Chihuahuan Desert.

Elevations to below sea level are found in the Mohave Desert (Death Valley) where the hottest temperatures for the U.S. have been recorded (USDA 1941). Precipitation is commonly less than seven inches annually, often less than five, while at places more than a year may pass between rains. Although most precipitation falls as rain, snows are common at higher elevations. Spring and fall winds increase evaporation rates and result in duststorms referred to as "sandsoons" in parts of the Chihuahuan Desert.

Breeding birds of the Mohave Desert include the Gambel's Quail, Roadrunner, Leconte's Thrasher, Scott's Oriole, and House Finch (Johnson field notes). Typical breeding birds of the Chihuahuan Desert include the Roadrunner, Ladderbacked Woodpecker, Mockingbird, Pyrrhuloxia, and Black-throated Sparrow (Wauer 1973).

Tropical-Subtropical Desertlands
(Sonoran Desertscrub)

The Sonoran Desert is the richest of North American deserts in vegetation series and associations as well as plant and animal species. This is especially true when wetlands are included. This desert is well named, for it is the only area in the United States that has a direct connection with the tropical Mexican (Sinaloan) thornscrub. As one drives north along the coastal lowlands from Sinaloa through Sonora, the vegetation changes gradually from a partially evergreen, closed thornscrub (with a fair number of trees) through a closed, deciduous thornscrub to an open desertscrub in northern Sonora and southern Arizona. Although many of the plant species which typify the Sinaloan thornscrub reach their northern limits south of the U.S.-Mexican boundary, a large percentage of the genera extend north into the United States. This is particularly true for woody legumes such as acacias, mesquites, paloverdes (Cercidium) and mimosas (Mimosa). The number of species of large cacti (trees and shrubs), e.g., Cereus spp., also diminishes as one progresses northward.

There is no similar ecological-geographic connection between the Tamaulipan Thornscrub of the eastern Mexican lowlands and the Chihuahuan Desert. In contrast to the Sonoran Desert, the Chihuahuan Desert is a relatively high desert, extending northward from the Mexican Plateau, which is situated between the Sierra Madre Oriental and the Sierra Madre Occidental.

Three major factors contribute to the great floral and faunal diversity of this region. We have already discussed the first, the influence of the Mexican Tropical Thornscrub. The second factor is the influence of the Southwestern highlands, consisting of the Colorado Plateau and various ranges of the Basin and Range Province

o the north, the southern end of the Rockies to the northeast, and a eries of conifer-clad mountains scattered throughout the Sonoran Desert. The third actor is a series of streams, starting with the Colorado River and its tributaries o the north, which connect the desert lowlands with these montane uplands. In ldition to providing pathways for movement of plant and animal species, a reticulum f streams and rivers also serves as a base for additional riverine ecosystems which ill be discussed in the following section on "Wetland Habitats." Thus, the floral nd faunal diversity which is apparent in the richness of the Sonoran Desert is fforded by these anastomosing ecosystems: montane and lowland; tropical and tem- erate; upland and wetland; desertland; grassland; scrubland; and woodland-forest.

Precipitation in the Sonora Desert varies from approximately 15 inches to less han 3 inches annually, occurring mainly as rain (USDA 1941). The region is noted for orrential summer thunderstorms during which a year's supply of rain may fall in a atter of days, or even hours. Winter rains and snows at higher elevations contribute o a bimodal precipitation pattern in most areas.

A few of the myriad of vegetation series of the foothills and bajadas include: aloverde-Mixed Cacti, Brittlebush-Ironwood (Encelia farinosa-olneyatesota) and, robably the most diagnostic plant association, Ambrosia deltoidea-Carnegiea gigantea = Cereus giganteus fide Benson 1969) (Triangle-leaf bursage-saguaro). Common breed- ng birds of these foothill, bajada types include the Elf Owl, Roadrunner, Costa's ummingbird, Gilded Flicker, 2/ Gila and Ladder-backed Woodpeckers, Brown-crested Wied's) Flycatcher, Verdin, Cactus Wren, Curve-billed Thrasher, Phainopepla, House inch, and Black-throated Sparrow.

Vegetation associations of the lower, often more poorly drained areas (e.g., ower Colorado Valley) include: Larrea divaricata-Ambrosia dumosa (Creosotebush-White ursage), Allenrolfea (Pickleweed), and Atriplex spp.-Prosopis juliflora torreyana Saltbush-Mesquite). Breeding birds include the Roadrunner, Verdin, and Leconte's hrasher.

WETLAND HABITATS

Wetland ecosystems are the most productive of western types. This is especially rue of riparian wetlands. At least three factors determine this high productivity: 1) greater number of species, (2) larger population densities (Table 2), and (3) im- ortance of these areas as refugia to wildlife under unfavorable conditions such as rought or fire.

Other papers in this symposium address this subject, especially in relation to iparian habitat. However, due to their importance we feel that our paper would be ncomplete without some discussion of these critical areas. Some of the Cottonwood- illow and associated mesquite riparian vegetation types are the most productive avian abitats in the western United States. These types support higher numbers of species s well as higher population densities when compared to the surrounding uplands.

A great amount of effort, manpower and money has been spent on endangered pecies. In a recent paper by Johnson et al. (1977) 166 nesting birds of the south- est lowlands were analyzed. These birds inhabit the brushlands, grasslands and iparian areas we are discussing. Of the 166 nesting species, 127 (or 77%) are in ome manner dependent on water-related habitat. Of this 77% dependent on water- elated habitat well over half (84 of the 166 species) are completely dependent on ater-related habitat. Only 39 species are nonriparian nesting birds. Thus, if

2/See Appendix I.

water-dependent habitats were completely destroyed in the Southwest (not including suburban and agricultural) 47% of our lowland nesting birds would be extirpated. Only 23% of our lowland nesting species would probably not be affected and 43 (26%) of the 166 species would be only partially affected.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Although the list of needs for nongame bird management is long, we shall here enumerate those we think are the most urgent. Although they are not necessarily in priority order, especially for your particular area of responsibility, we have listed the more pressing ones first.

1. Develop stronger riparian programs. During the last few years inland and coastal wetlands have received increased protection through legislation, executive orders, and agency policy. Although they are technically wetlands, most of our riparian areas have been ignored, glossed over, or mistreated intentionally or otherwise. Many resource management agencies, notably the U.S. Forest Service and Bureau of Land Management, are currently tightening their management policies for these vital riparian areas. However, proper management for this outstanding wildlife habitat has begun almost too late. An estimated 25% of our riparian ecosystems have been lost throughout much, if not most, of the United States (Korte and Fredrickson 1977; Samson 1979). Quick action is needed to keep from "running to stay behind" in this most critical resource management area.

2. Emphasize nongame recreation. The formulation of master plans, environmental statements, and other planning documents which devote most of their treatment of wildlife to half a dozen or a dozen game species while virtually ignoring several hundred nongame species continues to be a problem in resource management agencies. The politics behind this problem are complicated and long-standing, revolving around the basic fact that much past conservation was related to hunting, fishing and fees for the sale of licenses and permits for associated activities. As mentioned earlier, since little more than 10% of the population hunt and fish (and often much less) the inevitable question from the general public is "you seem to be managing 'wildlife' for this 10%, what are you doing for the other 90% of the taxpayers." We realize that this is a simplistic approach to a complex problem. However, if greater steps are not taken to bridge some of the current gaps between hunters, nonhunters and an increasing number of anti-hunters, a "taxpayers revolt" regarding wildlife management, rather than game management, may result.

3. Stress continuation of research to determine the optimum size, configuration, spacing and other characteristics for plots in varying habitat types. A great amount of this has been done for game species but very little for nongame birds. Censusing areas before and after habitat modification is important. For example, some of our research suggests that blocks of chaparral interspersed with other vegetation types, (commonly desert grassland or pinyon-juniper) may be more conducive to increases in nongame bird species diversity. Root plowing, to intersperse grassy plots with dense stands of chaparral on the Prescott National Forest, apparently increased bird usage, possibly due to the "edge effect" (Loe and White 1972). A good summary of censusing techniques is presented by Franzreb (1977).

4. Formulate more interagency nongame management policies and agreements. This is particularly important to management of wetlands and riverine habitats. These habitats, in addition to supporting our most valuable and productive ecosystems, commonly cross managerial and political boundaries. These ecosystems owe much of their value to the diversity associated with their large percentage of edge. The resulting, valuable edge effect is particularly vulnerable to mismanagement along

the stream. It is also affected by barriers created through different management policies and strategies along different segments of a stream. The implications of this to migrating birds are discussed by Rappole and Warner (1976) and Stevens et al. (1977). The impact of channelization, impoundment and other practices which destroy riparian habitat have reached a critical stage.

Current resource management practices must be reevaluated in the light of land management for nongame birds. Practices which are in particular need of examination include grazing; water "salvage" practices such as channelization, impoundment and phreatophyte control; use of river channels for agricultural and urban development; some type of lumbering; fire control and mistletoe control, to name a few. Steps must be taken soon to better evaluate and correct the impacts of many current management practices. Without this positive action some species which have already been greatly affected may eventually be pushed to the point of extinction. In some areas we are in danger of losing entire ecosystems if managers and scientists do not work together in formulating appropriate policy.

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APPENDIX I

Names of Birds Referred to in Text

Common Name	Scientific Name
Golden Eagle	*Aguila chrysaetos*
Scaled Quail	*Callipepla squamata*
Gambel's Quail	*Lophortyx gambelii*
Roadrunner	*Geococcyx californianus*
Great Horned Owl	*Bubo virginianus*
Elf Owl	*Micrathene whitneyi*
Burrowing Owl	*Athene cunicularia*
Costa's Hummingbird	*Calypte costae*
Gilded Flicker 1/	*Colaptes auratus chrysoides* 1/
Gila Woodpecker	*Melanerpes uropygialis*
Ladder-backed Woodpecker	*Picoides scalaris*
Brown-crested (Wied's) Flycatcher	*Myiarchus tyrannulus*
Horned Lark	*Eremophila alpestris*
Scrub Jay	*Aphelocoma coerulescens*
Common Raven	*Corvus corax*
White-necked Raven	*Corvus cryptoleucus*
Bushtit	*Psaltriparus minimus*
Wrentit	*Chamaea fasciata*
Cactus Wren	*Campylorhynchus brunneicapillus*
Mockingbird	*Mimus polyglottos*
Curve-billed Thrasher	*Toxostoma curvirostre*
Leconte's Thrasher	*Toxostoma lecontei*
Sage Thrasher	*Oreoscoptes montanus*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Water Pipit	*Anthus spinoletta*
Phainopepla	*Phainopepla nitens*
Black-throated Gray Warbler	*Dendroica nigrescens*
Scott's Oriole	*Icterus parisorum*
Eastern Meadowlark	*Sturnella magna*
Western Meadowlark	*Sturnella neglecta*
Pyrrhuloxia	*Cardinalis sinuata*
House Finch	*Carpodacus mexicanus*
Rosy Finch	*Leucosticte* spp.
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Rufous-crowned Sparrow	*Aimophila ruficeps*
Cassin's Sparrow	*Aimophila cassinii*
Black-throated Sparrow	*Amphispiza bilineata*
Sage Sparrow	*Amphispiza belli*
Brewer's Sparrow	*Spizella breweri*

1/Although the accepted name is Common Flicker this subspecies is ecologically and morphologically distinct from the other flickers.

USE OF MONTANE MEADOWS BY BIRDS

Fred B. Samson

Assistant Leader
Missouri Cooperative Wildlife Research Unit
U. S. Fish and Wildlife Service
112 Stephens Hall, University of Missouri
Columbia, MO 65211

ABSTRACT

Montane meadows comprise about 3.2 million ha under the jurisdiction of the U. S. Forest Service, the Bureau of Land Management, and state and private ownership. Relatively few species of birds breed on montane meadows, but meadows serve as important foraging areas for avian communities associated with nearby riparian or forest habitats. Recommendations for management of montane meadows include: (1) care should be exercised in grazing or other land-use prescriptions such as fire, considering their apparent accelerative effect on meadow succession; (2) information is needed on the effect of meadow size on the diversity of breeding and foraging birds to fully predict the effect of land use changes; and (3) detailed studies involving marked individuals rather than singing male counts are needed to ensure accurate estimates of densities and essential habitat needs of breeding birds.

KEYWORDS: montane meadows, meadow succession, nongame wildlife management, avian ecology.

In successfully occupying higher elevations, birds have accommodated a complex of environmental conditions--extensive solar radiation particularly in the ultraviolet spectrum, reduced air and oxygen pressure, intense night cooling by reradiation of heat, low atmospheric humidity, persistent wind, and, in winter, deep snowpack (Brinck 1974). Thus, high montane avifaunas are generally poor in species; populations often are small, reflecting low primary productivity; and densities vary from locale to locale (Dorst 1974). The severe environment, however, has not precluded extensive resource development and recreational use by man (Turner and Paulsen 1976, Johnson 1979), and, in some regions of the world, the montane is the most endangered of all ecosystems (Eckholm 1975). Importantly, the distribution, abundance and ecological relationships of most montane avian communities are not well known. The purpose of this report is to review avian use of a western U. S. montane ecotype--the montane meadow--emphasizing (1) a description of vegetation,

(2) geographic distribution, (3) local distribution, and (4) population characteristics important to management.

MONTANE MEADOWS

The meadow as a principal type of vegetative physiognomy consists of "dense grassland, usually rich in forbs, with grasses having broad and soft blades, and occurring in relatively moist habitats" (Daubenmire 1968:251). In the western United States, montane meadows vary in size from a few to several hundred hectares, lie interspersed as "islands" among subalpine forests of lodgepole pine (scientific nam in Appendix 1), quaking aspen, Douglas-fir, Englemann spruce-subalpine fir, and ponderosa pine and generally are located on gentle slopes, broad or rounded ridges, or along streams, rivers, or other water sources. Within this broad description, meadows are reported as "wet," those along small streams with dense and diverse grass, forb and shrub vegetation, or "dry," often a transition between wet and forested areas but sustaining a dense mixture of grasses and forbs with scattered pines or aspen stands (Patton and Judd 1970, Austin and Perry 1979).

Western montane plant communities, however, are difficult to characterize, sinc western mountain ranges differ geologically, climatically, and biologically. For example, the Olympic Mountains were produced by two periods of diastrophism (Kuramot and Bliss 1970), and the high Cascades are constructed of extrusive volcanics (Price 1978). Total annual precipitation ranges from over 500 cm in the Olympic Mountains to less than 50 cm in the Intermountain Region. The complex plant communities on mountain meadows comprise several hundred species of sedges, grasses, forbs, and small shrubs and reflect a number of factors--climate, site and edaphic conditions, surface age, mountain mass, and different historic immigration routes (Chabot and Billings 1972). Fortunately, detailed ecological studies that include flora of subalpine meadows are available for the Great Basin (Hayward 1945, 1952, Ellison 1954, Lewis 1970, Cronquist et al. 1977), the Pacific Northwest (Merkle 1951, Fonda and Bliss 1969, Kuramoto and Bliss 1970, Hitchcock and Cronquist 1973), the Sierra Nevada (Mooney et al. 1962, Chabot and Billings 1972), and the Rocky Mountains (Costello 1944, Hurd 1961, Patton 1963, Mehringer et al. 1977). In contrast to plant communities, the dynamics of individual sedge, grass, or forb populations on mountain meadows have not been extensively investigated (Scott and Billings 1964, Gorham and Somers 1973, Johnson and Caldwell 1975, Thilenius 1975, Briggs 1978). It is known that "floral aspects of mountain grasslands differ markedly from one year to another and production of viable seed by individual plant species probably varies even more" (Turner and Paulsen 1976:5). Presumably this variation is influenced by microclimate and annual variation in moisture and temperature. These factors also influence total herbage produced on meadows which, in a study in Apache National Forest, Arizona, varied from 834 to 1741 kg per 0.4 ha on a wet meadow versus 19 to 131 kg per 0.4 ha on a dry forest floor (Patton and Judd 1970).

Investigations of the interplay of man-related and natural factors affecting succession on montane meadows have suggested those that influence tree invasion to be most important (Fig. 1). In a thorough review of the impact of grazing (records from 1914-1975) on tree invasion of subalpine meadows in the Wind River Mountains, Wyoming, Dunwiddie (1977) suggested moderate grazing by cattle results in extensive tree establishment because of reduced competition from a mat of meadow vegetation (Fig. 1). Furthermore, cessation of grazing historically coincided with lack of invasion of trees. Dunwiddie (1977) also pointed to the possible importance of changing climate on the extension of trees into formerly treeless areas, results similar to those of Fonda and Bliss (1969), Franklin et al. (1971), Douglas (1972), and Mehringer et al. (1977). Fire, another natural factor, may create openings for meadows (Patton 1963), but several microenvironment variables determine whether trees reinvade (Kuramoto and Bliss 1970). Despain (1973:350), also working in Wyoming, states "caution should be exercised when interpreting the existence of grasslands

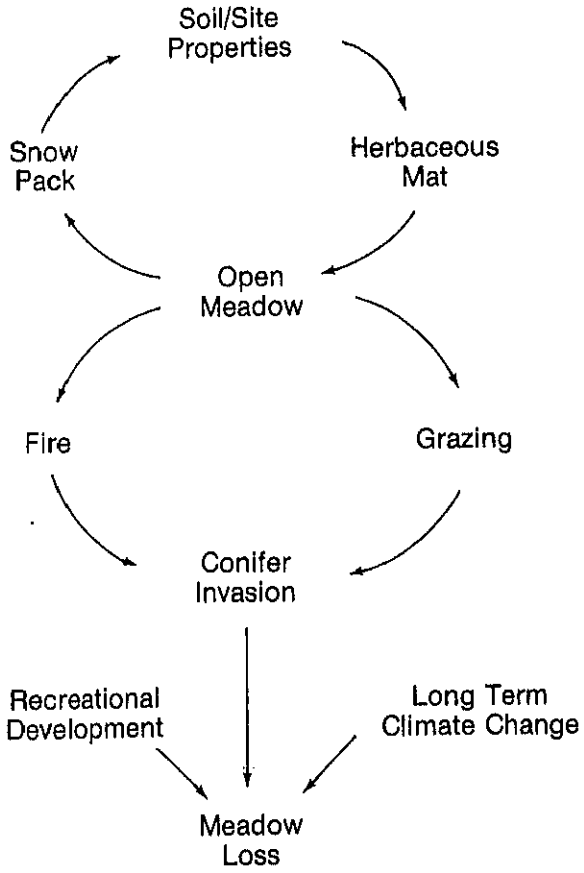

Figure 1.--Generalized schematic representation of vegetative succession on montane meadows (following Despain 1973, Dunwiddie 1977, Weaver and Dale 1978, and others).

of parks in otherwise heavily timbered forests as indicating fire." Rather, herbaceous cover, soil properties, and patterns in snow accumulation appear significant in maintaining open mountain meadows.

DISTRIBUTION OF BIRDS ON ALPINE MEADOWS

Recent studies of montane avian distribution consider mountains ecologically similar to islands, i.e., rising from generally level low-lying areas with their colonization dependent upon conditions and history of the surrounding environment (Brinck 1974, Johnson 1975, Behle 1978, Brown 1978, Thompson 1978). Among hypotheses proposed to explain variation in number of bird species from place to place, the theory of island biogeography (MacArthur and Wilson 1967) has produced good predictions of species numbers, incorporating the size of the area studied and the degree of isolation between similar habitats (Fig. 2). Thompson (1978), working in central Montana, has shown that area of a mountain in the Sweet Grass Hills can predict the number of summer resident bird species. Brown (1978:209) reported "insular area is the single variable that accounts for most of the variability in both bird and mammal species diversity" in the Great Basin (Fig. 3). Similarly, in the Great Basin, Johnson (1975) reported mountain area, inasmuch as area and habitat variety are closely correlated, was important in imposing limits on the distribution of birds.

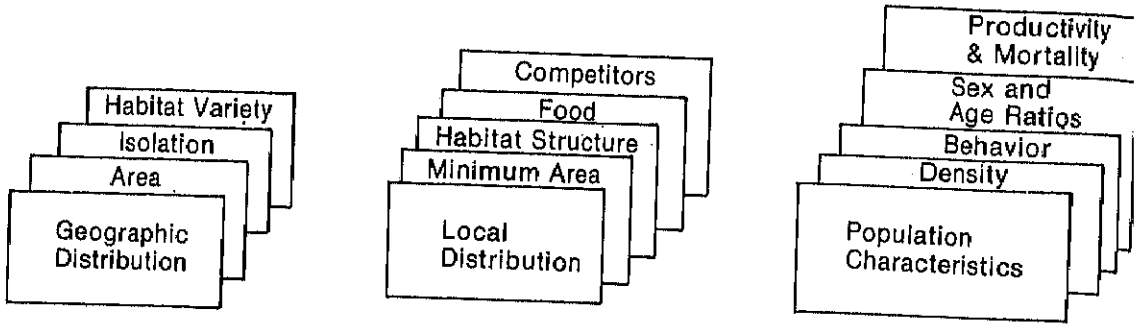

Figure 2. Summary of factors important in avian geographic and local distribution and in management of populations on montane meadows.

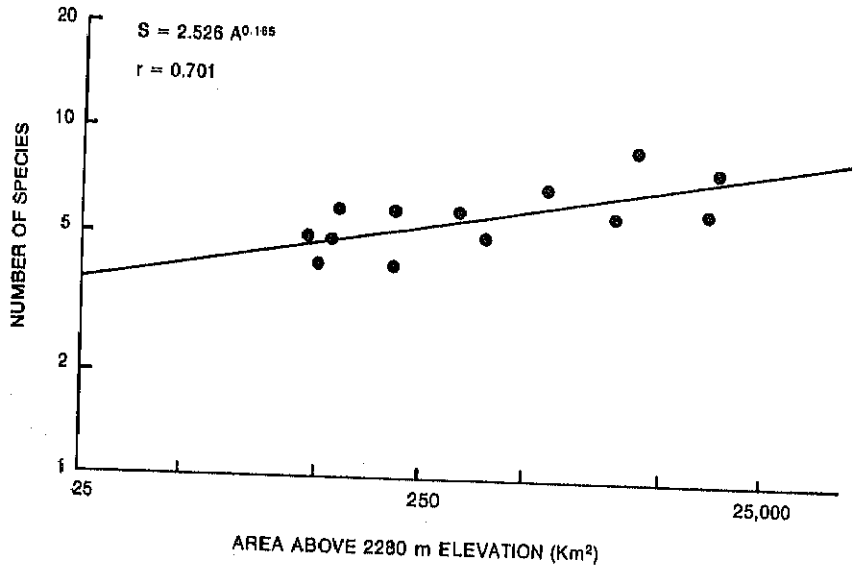

Figure 3. Figure redrawn following Brown (1978:215) with dots representing individual montane "islands" in the Great Basin. The relationship between montane area and number of bird species is significant ($r = 0.701$, $P<.01$).

In addition to mountain area, isolation between mountains or mountain ranges is proposed as an influence on avian distribution (Fig. 2). For example, Johnson (1975: 549) pointed out that historically the northern three-toed woodpecker "probably used mountain top forests as a stepping stone along an area from the Wasatch Mountains through the Pine Valley Mountains of southwestern Utah, then northward through southeastern Nevada to the Snake Range," rather than directly crossing the large deserts of western Utah. However, whether barrier width is important to mountain meadow birds is questionable. Most meadow species are long-distance migrants and are able to cross extensive inhospitable environments with relative ease. Thus, isolation presumably plays a relatively minor role.

Habitat variety (Fig. 2), i.e., the presence of water, meadows, shrubs, forest canopy, etc., is closely associated with the concept of avian guilds. A guild may be defined as "a group of species that exploit the same class of environmental resources in a similar way...without regard to taxonomic position" (Root 1967:335). In the West, the number of guilds exploiting a mountain is similar providing parallels in habitat variety are evident (Johnson 1975). Membership within a guild, however, may be dramatically different dependent upon the general productivity of the mountain range. For example, in the Great Basin 14 species in 9 guilds comprise a "standard" group (terminology of Johnson 1975). Nearly all species in the "standard" group are "fundamentally different in place or style of feeding, in food taken or all three respects," i.e., timber hole drilling, timber foliage foraging, high aerial foraging, low aerial foraging, etc. (Johnson 1975:556-557). Near Crater Lake, Oregon, a more productive locale, 66 boreal species form a "continental" complex, yet only 9 guilds are represented. Thus, the general partitioning of habitat-food resource places and activity is similar between distinct mountain ranges.

LOCAL DISTRIBUTION

Size of an area (Fig. 2) is predictive of the number of birds present in the "islands" of several temperate habitats--lakes and lake shores (Sillen and Solbreck 1977), urban parks (Gavareski 1976), southeastern mixed forests (Whitcomb 1977), Wisconsin hardwood woodlots (Tilghman 1977), eastern deciduous forests (Galli et al. 1976), lowland hardwoods (Graber and Graber 1976), and oak-hickory forests (M. Mitchell, pers. comm.). An example for a grassland ecotype is provided in Fig. 4. Several of these studies also have shown area-sensitivity in some species that require a minimum area to survive. When their respective habitats are fragmented, the area-sensitive species face localized extirpations (Forman et al. 1976, Leck 1979).

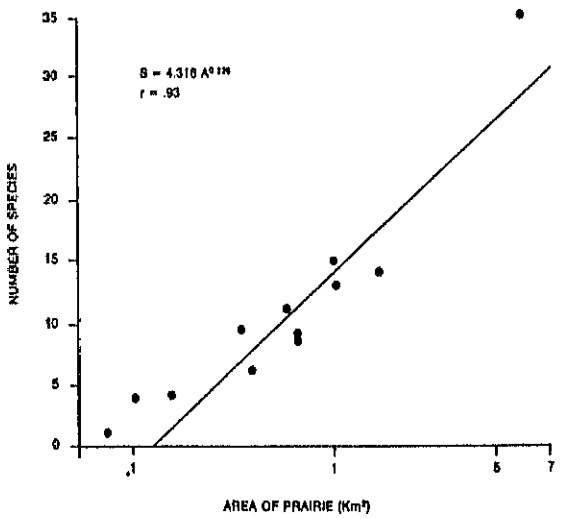

Figure 4. The relationship (r = .93, P<.01) of area to number of breeding bird species on 12 tall grass prairie relicts (size .5 to 540 ha) in southwestern Missouri, 1979.

Precise estimates of minimum area requirements for species breeding on montane meadows are not available. The probable existence of a species-area relationship for birds breeding on montane meadows in northern Utah, however, is evident in preliminary observations by K. G. Smith (pers. comm.). On small meadows (<2 ha), only the dark-eyed junco nests, whereas the Brewer's, vesper, and white-crowned sparrows breed on meadows of about 10 ha. However, information is needed to develop a predictive species-area relationship to include all species (Fig. 5) both during the breeding season and during migration.

Habitat structure is a second component (Fig. 2) potentially influencing avian use of a montane meadow. The relationship between singing or displaying males and structural characteristics of the vegetation is known for several habitat types, particularly the eastern deciduous forest (James 1971). In contrast, little is known of this

relationship for males singing on montane meadows. Thus, whether the geometric organization of singing males on a mountain meadow reflects social interactions between individuals of several species or independent responses of a specific nat to a complex of vegetational or abiotic characteristics has not been extensively investigated. It is known that the shape, location, and number of white-crowned sparrow territories in spring on a meadow reflects extent of snow cover (Morton et al. 1972). After the snow-melt, mountain white-crowned sparrows forage in open ar or on bare ground, yet these areas, as well as sources of water, may change in suitability from year to year. These annual changes in suitability along with the general insular character of mountains may account in part for the substantial year-to-year changes in abundance in montane avifauna noted by several authors (Johnson 1975, Thompson 1978). There are reports describing habitat elements for species nesting on montane meadows--western meadowlark, vesper sparrow, and Brewer' sparrow and others (Linsdale 1938, Salt 1957).

Competition (Fig. 2) is a third variable to impose limits on the distribution montane birds (Terborgh and Weske 1975). For example, in the northern Rockies wher the ranges of the white-tailed, rock, and willow ptarmigan overlap, summer overlap habitat is small--the white-tailed in cliffs, rocks, and fellfields at high elevati the willow in lower wet meadows, tussocks, riparian shrubs, and valley slopes; and the rock on middle slopes with heath tussocks, low shrubs, and dry meadows (Weeden 1964, Hoffmann 1974). In the central Rockies where only the white-tailed ptarmigan breeds, the species occupies the full range of habitat types suggesting that competitive interactions operate in areas of congener sympatry. Providing another example, the water pipit nests in moist alpine wet meadows in the Rockies yet is restricted to dry meadows or fellfields in the arctic by the red-throated pipit (Voous 1960, Williamson et al. 1966). However, as with minimum area and habitat structure, the impact of competition on the distribution or abundance of birds breeding in montane meadows needs to be resolved.

Spring and summer food availability (Fig. 2), a fourth potential variable influencing avian use of montane meadows, is highly dependent on climatic conditions, especially temperature (Roeder 1953, Turner and Paulsen 1976). Although diet of several species breeding on montane meadows is known (Austin 1968, Wiens and Rotenberg 1979), the impact of availability of food on initiation of breeding, egg laying, molt, and migration has not been well documented. It is known that adult meadow pipits breeding on a British mountain farm grassland collected less than 1 percent of available adult tipilids, their principal food for their nestlings and themselves (Seel and Walton 1979), suggesting an abundance of available food. Moreover, in an extensive assessment of diet niche relationships among North American grassland and shrub steppe birds, Wiens and Rotenberg (1979:254) found "that food is not normally limiting to bird populations in these systems." Few if any other published reports have provided empirical evidence that food is limiting during the breeding season in montane or other habitats (Fretwell 1978).

Importantly, several species that breed in habitats surrounding montane meadows regularly forage in meadows again suggesting that food is abundant. Thompson (1978) reported several raptors--Cooper's hawk, red-tailed hawk, golden eagle, marsh hawk, merlin, and American kestrel--are associated with montane grasslands in Montana (Fig. 5). At least 6 aerial insectivores--the poor-will, common nighthawk, tree swallow, violet-green swallow, rough-winged swallow, barn swallow--and 3 nectarivores--broad-tailed, calliope, and rufous hummingbirds--forage extensively in meadows (Salt 1957, Thompson 1978; K. G. Smith, pers. comm.; F. B. Samson, unpub. data). Although a cavity nester, the mountain bluebird during the breeding season sallies or hovers to prey on meadow insects. Another forest-dwelling cavity nester, the common flicker, regularly forages on the ground in open meadows as do several species nesting in riparian willows.

during migration and at least two alpine-tundra nesters, the gray-crowned rosy finch and black rosy finch, forage in meadows during spring migration.

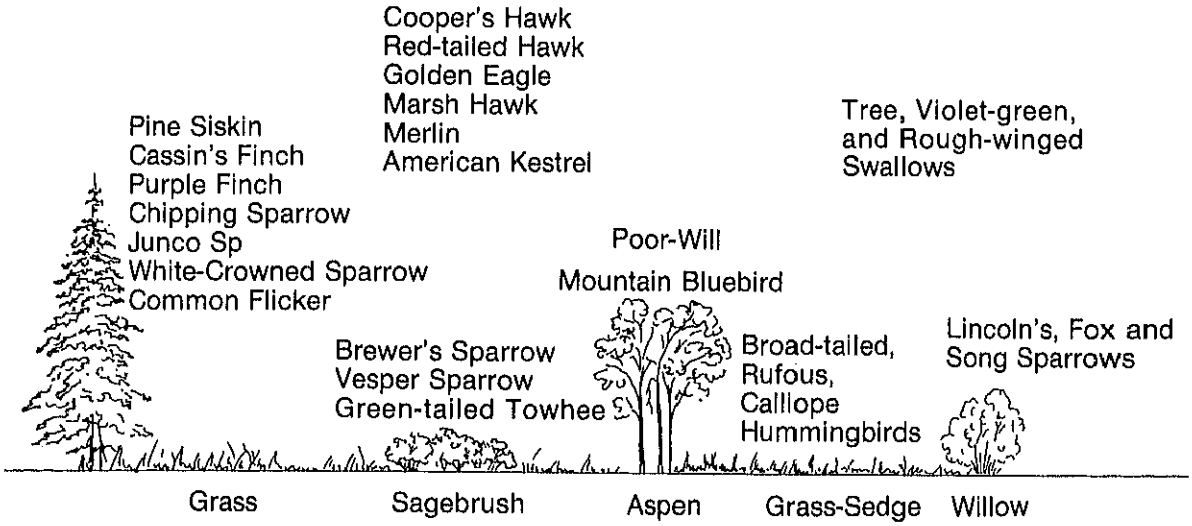

Figure 5. Generalized schematic representation of foraging place of birds using a montane meadow in the breeding season (Salt 1957, Thompson 1978). Birds nesting on montane meadows include Junco spp., the white-crowned, Brewer's, and vesper sparrows, and the green-tailed towhee.

POPULATIONS

Studies of particular species often involve several variables--density, behavior, sex and age ratios, mortality, and survival rates (Fig. 2). In addition to monitoring annual changes in population numbers, estimates of densities of widespread breeding birds have been used as an "indicator" of habitat condition particularly in relation to land use. To make valid comparisons in bird density between years on a site or among sites, several authors suggest census of individually marked birds rather than reliance on observations of unmarked birds such as singing males (Jarvinen et al. 1978, Seel and Walton 1979, and others). Several factors account for this recommendation, primarily annual changes in the relative abundance of breeding and nonbreeding males, contrasts in singing frequency of mated versus unmated males, and age-specific habitat use.

Two examples of birds associated with mountain meadows illustrate the point. In a study of the mountain white-crowned sparrow from 1968 to 1970 involving marked birds (Morton et al. 1972), overall male to female ratios of captured birds were 1.29:1.0 in adults and 1.27:1.0 in immatures. From year to year, sex ratios varied from 1.45:1.0 in adults and 1.5:1.0 in immatures in 1968 to 1.2:1.0 and 1.1:1.0 in 1970. Number of males, therefore, may exceed those of females by up to 50 percent. After pairing, mated males virtually cease to sing, but unattached males, primarily yearlings, continue to sing, intent on attracting a mate (Blanchard 1943; Baptista, pers. comm.). However, because of social interactions with older mated males, yearlings may be forced to occupy less preferred habitat (Ralph and Pearson 1971). Thus, males singing frequently in late May or June can clearly be unmated males potentially in suboptimal habitat.

In Cassin's finch, a second example, yearlings (which do not breed to any extent) comprised 22.2 percent of all males banded in 1971, 48.6 percent in 1972, and 27.2 percent in 1973 in a study reported from northern Utah (Samson 1976). In 3 years of that study, all males and females arrived simultaneously on a breeding area, and all age classes of males sang until nesting, which occurred in late May or early June (Samson 1978). After nest construction, breeding males ceased to sing, directing their energies and activities toward feeding the female and, later, young in the nest. The reduction in singing activity also substantially reduced a cue to attract potential predators to the female and nest. Yearling, nonbreeding males continued to sing as late as August, using perches in an array of habitats, both preferred and clearly suboptimal. The average territory, which centered around the female, had a mean radius of 4.1 m (total area 52.4 m^2). Cassin's finches nest in colonies in patterns similar to other members of the subfamily Carduelinae (Peiponen 1962, Hilden 1969, Tast 1970, Newton 1972). It is not surprising then that comparisons of the above density estimates contrast greatly to those based solely on singing males such as those regularly reported in American Birds (Van Velzen 1975, 1977), or in other surveys relying on singing males (Austin and Perry 1979). Therefore, without documentation of the vocal behavior, sex ratio, age ratio, and other characters of individual populations, it appears very difficult to accurately estimate density of breeding birds associated with mountain meadows. Other authors, too, have offered warnings on the use of singing males to estimate breeding numbers in their habitats (Davis 1965, Best 1975).

Productivity (Fig. 2) is an additional important characteristic in the management of a species. For birds breeding at high latitudes, weather has been reported the major factor limiting productivity (Jehl and Hussel 1966, Jehl 1968). In montane meadows, weather's effect may be more indirect than direct. Morton et al. (1972) observed that fewer pairs established territories and built nests if a meadow remained snow covered into late spring. Moisture, however, persisting through the summer because of the late snow cover, created very favorable conditions for raising young. In fact, more young were produced when fewer pairs nested and moisture conditions in late summer were favorable. These authors point out "the number of pairs present in a given year was not a good indication of productivity for the meadow" (1972:161). Other effects of weather are known, particularly on the general phenology of breeding and molt activity. For example, Cassin's finch may delay onset of nesting activities if weather conditions remain unfavorable late into spring (Samson 1976) and weather affected the nesting schedule of water pipits in the alpine tundra in Montana (Verbeek 1970). Renesting is uncommon in many montane nesters. The 50-60 days required for the breeding cycle--nest construction to fledgling independence--and 70-80 days for molt nearly comprises the entire environmentally favorable period at high altitudes.

Mortality (Fig. 2) during the breeding season in birds on montane meadows may reflect several causes, most importantly predation, weather, trampling by sheep, and human interference. Among reported potential or observed predators, the deer mouse, long-tailed weasel, coyote, badger, Clark's nutcracker, and ground squirrels appear most important (Verbeek 1970, Morton et al. 1972). Nesting losses due to predation in the mountain white-crowned sparrow have ranged as high as 30 percent (Morton et al. 1972), but estimates of losses for other meadow species are not available. The direct effects of weather vary from freezing of incubating females to flooding of nests by spring rains concurrent with snowpack melt (Morton et al. 1972). Tourists and fishermen were considered by Morton et al. (1972) a likely cause of nest abandonment in the mountain white-crowned sparrow. Hikers, motorcycles, and horses also trample montane grasslands causing damage to habitat (Weaver and Dale 1978).

Few nongame birds overwinter on montane meadows, yet events during the nonbreeding season may be most important to the population dynamics of species breeding on mountain meadows. Lack (1966) argued annual changes in breeding numbers of birds, both annual residents and migrants, reflected food-related mortality from early fall through winter. Subsequent studies by Newton (1964), Fretwell (1969, 1972), Pulliam and Enders (1971), Krebs (1971), Davis (1973), Slagsvold (1975), Samson (1976), Jones and Ward (1976), Samson and Lewis (1979), among others tend to support the contention that the size of a breeding population is influenced by events of the nonbreeding season.

SUMMARY AND RECOMMENDATIONS

Montane meadows comprise about 3.2 million ha under the jurisdiction of the U. S. Forest Service, the Bureau of Land Management, and state and private ownership (USDA 1975). To summarize this review of avian use of montane meadows, I offer the following

(1) To maintain open montane meadows, care should be exercised in grazing or other land-use prescriptions (fire, for example) considering their apparent accelerativ effect on succession (Fig. 1). Wet meadows are particularly susceptible to roads and trails which should be located in adjacent dry forests (Patton and Judd 1970).

(2) Area, isolation, and habitat variety are important variables imposing limits on the geographical distribution of birds in western mountains (Fig. 2). Birds breeding in western mountains function ecologically in nine role categories with membership varying greatly, depending on productivity and other factors characteristic of a mountain range.

(3) Relatively few species breed on montane meadows, yet meadows are important foraging areas for members of adjoining avian communities, particularly those in forest or riparian habitats. The effect of size of a montane meadow (Fig. 2) on diversity of breeding or foraging birds, however, is not precisely known. The need for the information is clear, since without it the effect of land-use change on avian communities using meadows cannot be fully predicted.

(4) Slagsvold (1976:197-222) has noted "changes in song activity affect the discovery chance of birds." Observers are also biased by song activity (Enemar et al. 1978). Song activity in a species, however, is influenced by many factors including stage of the nesting cycle, population age and sex structure, and year-to-year variations in population structure. Importantly, nonbreeding birds, through social interactions with breeding birds, generally are relegated to less preferred habitat. When one combines observer bias toward song activity, the higher singing rates of nonbreeding males, and the use of less preferred habitat by nonbreeding (often yearling) males, what emerges is descriptive of habitat needs for the nonbreeding portion of a species population. Thus, detailed studies involving marked individuals rather than singing male counts are recommended to ensure accurate estimates of densities of a population and the essential habitat needs of breeding birds.

(5) Lastly, this review has essentially dealt with ecological issues similar to most wildlife management studies or reports. However, the future of montane meadows and associated avifauna may not depend on ecological variables but economic ones. Future research for this ecotype should attempt to merge ecological and economic considerations.

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APPENDIX 1

Birds	Meadow use[1]
Cooper's hawk (Accipiter cooperii)	B
Red-tailed hawk (Buteo jamaicensis)	B
Golden eagle (Aquila chrysaetos)	B, D
Marsh hawk (Circus cyaneus)	B, C
Merlin (Falco columbarius)	
American kestrel (F. sparverius)	B
Willow ptarmigan (Lagopus lagopus)	
Rock ptarmigan (L. mutus)	
White-tailed ptarmigan (L. leucurus)	
Poor-will (Phalaenoptilus nuttallii)	B
Common nighthawk (Chordeiles minor)	B
Common flicker (Colaptes auratus)	B
Northern three-toed woodpecker (Picoides tridactylus)	
Broad-tailed hummingbird (Selasphorus platycercus)	B
Rufous hummingbird (S. rufus)	
Calliope hummingbird (Stellula calliope)	
Violet-green swallow (Tachycineta thalassina)	B
Tree swallow (Iridoprocne bicolor)	B
Rough-winged swallow (Stelgidopterux ruficollis)	B
Barn swallow (Hirundo rustica)	B
Clark's nutcracker (Nucifraga columbiana)	B
Mountain bluebird (Sialia currucoides)	B
Water pipit (Anthus spinoletta)	
Meadow pipit (Anthus pratensis)	
Red-throated pipit (A. cervinus)	
Western meadowlark (Sturnella neglecta)	A
Purple finch (Carpodacus purpureus)	
Cassin's finch (C. cassinii)	B
Gray-crowned rosy finch (Leucosticte tephrocotis)	C
Pine siskin (Carduelis pinus)	
Black rosy finch (Leucosticte atrata)	C

APPENDIX 1 (continued)

Birds	Meadow use[1]
Green-tailed towhee (Pipilo chlorurus)	A
Vesper sparrow (Pooecetes gramineus)	A
Dark-eyed junco (Junco hyemalis)	A
Brewer's sparrow (Spizella breweri)	A
Chipping sparrow (S. passerina)	
White-crowned sparrow (Zonotrichia leucophrys)	A
Fox sparrow (Passerella iliaca)	A
Lincoln's sparrow (Melospiza lincolnii)	A
Song sparrow (M. melodia)	
Mammals	
Deer mouse (Peromyscus maniculatus)	
Long-tailed weasel (Mustela frenata)	
Coyote (Canis latrans)	
Badger (Taxidea taxus)	
Ground squirrel (Citellus spp.)	
Plants	
Lodgepole pine (Pinus contorta)	
Ponderosa pine (P. ponderosa)	
Englemann spruce (Picea engelmannii)	
Douglas-fir (Pseudotsuga menziesii)	
Subalpine fir (Abies lasiocarpa)	
Quaking aspen (Populus tremuloides)	

[1] A = Bird dependent on meadow for nesting and feeding; B = Bird dependent on meadow for feeding; C = Meadow use during migration; D = Meadow use during winter.

POST-FIRE SUCCESSION OF AVIFAUNA IN CONIFEROUS FORESTS OF YELLOWSTONE AND GRAND TETON NATIONAL PARKS, WYOMING

Dale L. Taylor

Research Biologist
South Florida Research Center
Everglades National Park

and

William J. Barmore, Jr.

Research Biologist
Grand Teton National Park

ABSTRACT

Yellowstone and Grand Teton National Parks have been zoned to allow certain natural fires to burn until they self-extinguish. The effect of these natural fires on avifauna in the two parks is reported in this paper.

Breeding bird populations in burned lodgepole pine or spruce-fir-lodgepole pine forests of the following post-fire ages are analyzed: MODERATE BURN 1, 2, 3 years; SEVERE BURN 1, 2, 3, 5, 7, 11, 13, 17, 25, 29, 43, 44, 45, 57, 61, 111, 115, 300, 304 years; UNBURNED SPRUCE-FIR WITH SOME LODGEPOLE PINE, and UNBURNED SPRUCE-FIR.

Highest populations and greatest biomass occurred from 5-29 years post-fire. Bird density, species composition, and diversity on moderately burned spruce-fir-lodgepole were more like those on unburned spruce-fir than on other seral stages. Greatest biomass of air-soaring, foliage-seed, timber-drilling, ground-insect, and ground-seed feeding categories occurred where the forest canopy had not closed. Biomass of foliage-insect and timber-searching was greatest where the forest canopy had closed. Canopy closure affected avifauna more than fire did.

KEYWORDS: birds, fire, succession, biomass, feeding category, coniferous forest.

INTRODUCTION

Prior to the late 1960's National Park Service policy was to suppress all natural and man-caused fire in national parks. (Everglades National Park has been an exception to this policy since 1958.) Since then, there has been a growing awareness of the vital role that fire played in the dynamics of many pristine ecosystems. Recommendations by the Secretary of the Interior's Advisory Board on Wildlife Management (Leopold 1963) and subsequent research on fire resulted in new management policies which recognize the role of fire in many natural ecosystems (U.S. National Park Service 1979). The new policies require a fire management plan for all National Park Service areas and provide for use in park management of prescribed natural fire (fire of natural origin--not man-caused--which is allowed to burn under prescribed conditions) and/or prescribed fire (fire set by man under specified conditions to accomplish specified objectives within a specified area).

Fire management plans have been in effect since 1972 in Yellowstone and Grand Teton National Parks. Research during the 1960's and early 1970's (Taylor 1969, 1973b, 1974; Loope 1971; Loope and Gruell 1973; Houston 1973; Gruell and Loope 1974; Barmore et al. 1976) documented the importance of fire in the pristine ecosystems of these parks and provided the scientific foundation for fire management plans. Some natural fires have been allowed to burn in specified zones of both parks since 1973.

This report summarizes succession of birds following natural fire in coniferous forests of the two parks (Taylor 1969, 1973a, 1973b, 1976; Barmore et al. 1976). Research on the relationships between fire and nonhunted bird species is rare (Thomas et al. 1975) but includes studies by Marshall (1963), Bock and Lynch (1970), Emlen (1970), Kilgore (1971), Roppe (1973) and Theberge (1976).

Study Areas

Ten areas ranging from 1 to 304 years post-fire plus two others of unknown age since fire (perhaps unburned) were studied in the two parks (Table 1). Sampled areas ranged from 40 to several hundred acres in size. Current vegetation is lodgepole pine (*Pinus contorta*) or spruce-fir (*Picea engelmannii-Abies lasiocarpa*) forest. More detailed descriptions of the study areas are in Taylor (1969) and Barmore et al. (1976).

Two fire intensities were sampled on the 3492 acre (1414 ha) Waterfalls Canyon burn in Grand Teton National Park: Severe--all above ground vegetation was killed by intense crown fire; Moderate--40% or more of the tree overstory was alive 1 year post-fire and part of the grass-forb-shrub understory was unburned. Unburned stands of spruce-fir-lodgepole pine (UI) and spruce-fir (UII) adjacent to the Waterfalls Canyon burn were also sampled. These stands were characteristic of the severely and moderately burned areas prior to the fire.

Current vegetation of all study areas in Yellowstone National Park developed, or was assumed to have developed (the 1856 and 1667 burns), following severe crown fire. Study areas were at 6800 feet (2073 m) in Grand Teton National Park and 8000-8200 feet (2440-2500 m) in Yellowstone. Succession will be more rapid at the lower elevations.

Table 1. Characteristics of bird census plots in Yellowstone and Grand Teton National Parks.

Location	Elevation	Type of Fire*	Vegetation Type at Census	Year Burned	Years Post-Fire When Censused
Grand Teton	6800 ft	S	Severe burn: grass sedge-forb	1974	1, 2, 3
Grand Teton	6800 ft	M	Moderate burn: spruce-fir, old lodgepole pine	1974	1, 2, 3
Yellowstone	8200 ft	S	Burned forest, early succession	1966	5
Yellowstone	8200 ft	S	Burned forest, early succession	1960	7, 11
Yellowstone	8200 ft	S	Burned forest, shrub stage	1954	13, 17
Yellowstone	8200 ft	S	Burned forest, shrub young forest stage	1942	25, 29
Grand Teton	6800 ft	S	Dense lodgepole forest, some open areas	1932	43, 44, 45
Yellowstone	8000 ft	S	Dense lodgepole forest, closed canopy	1910	57, 61
Yellowstone	8200 ft	S	Dense lodgepole forest	1856	111, 115
Yellowstone	8200 ft	S	Dense lodgepole forest	1667?	300, 304
Grand Teton	6800 ft	UI	Dense spruce-fir forest some lodgepole	unknown	
Grand Teton	6800 ft	UII	Dense spruce-fir forest	unknown	

* S = Severe burn with both crown and ground fire; M = moderate burn, spotty fire in understory and overstory; 40% or more of overstory remained 1-year post-fire; U = unburned; UI = mean tree age of 86 years, range 22-219; UII = climax stand. UI and UII were censused 3 consecutive years.

METHODS

Breeding bird density was estimated by the transect survey method (Haapanen 1965, Kendeigh 1944) during four censuses on each study area. D. Taylor made all bird counts. Transect counts, when well standardized, are the preferred census technique if large areas must be sampled in a short time (Robbins 1978). Breeding birds were considered to be those within a 75 ft. (23 m) wide belt on each side of a 1000 yd. (914 m) or 1200 yd. (1100 m) paced transect. Census area totaled 10.3 acres (4.2 ha) or 12.4 acres (5.0 ha). Birds outside the belt were recorded as present in the study areas. Censuses were conducted from daylight to approximately 0800 during June and in the first two weeks of July. Populations of pine siskins and red crossbills were not estimated since these species characteristically moved through the areas in flocks. When a species such as the pine siskin was consistently present in an area, one pair per 100 acres was assumed to be present.

Classification of birds into feeding categories according to foraging level and food type follows Salt (1957). Bird biomass calculations are from Grand Teton National Park (Salt 1957). Bird species diversity is expressed as the Shannon-Weaver index (Pielou 1966). Bird names follow the AOU checklist (Appendix 1).

CHANGES IN DENSITY AND SPECIES COMPOSITION

Reasons for the high variation between years in estimated total bird density (as much as 45% for short time periods of 2-4 years, Fig. 1) are unknown but probably reflect the high variance inherent in all bird census methods (Dice 1952). Coefficients of variation for total density of breeding pairs on Grand Teton study areas (4 censuses/study area/year) averaged 27% (range 16-47, N = 15 C.V.'s) and were much higher for most individual species (up to 200%). However, the generally declining trend in total density of breeding pairs from youngest to oldest seral stages is consistent (Fig. 1).

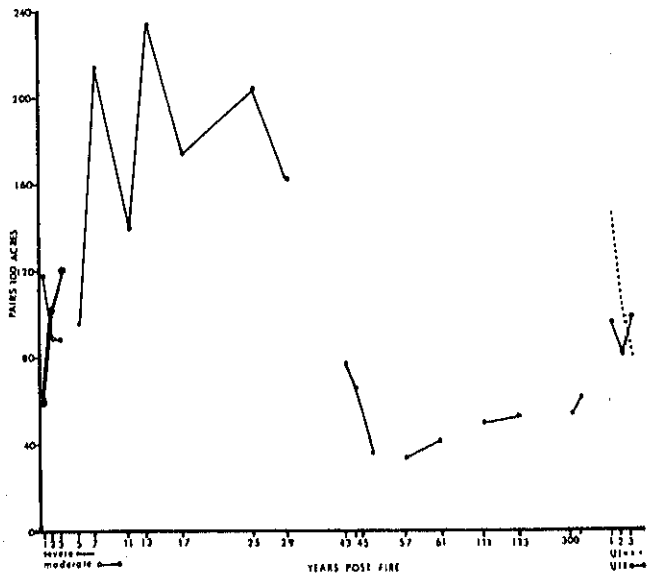

Fig. 1. Density of breeding pairs in seral vegetation following fire in coniferous forests of Yellowstone and Grand Teton National Parks. Unburned areas UI and UII were censused 3 consecutive years.

The most obvious change in species composition was the presence of northern three-toed and black-backed three-toed woodpeckers the first three years following fire and their absence or very low density thereafter (Table 2). Prior to the Waterfalls Canyon fire, the northern three-toed woodpecker was listed as rare, and the black-backed three-toed woodpecker was not listed for Grand Teton National Park (Grand Teton Natural History Association 1973) where a sizeable fire had not occurre since 1932. Periodic fires are apparently important to these two woodpecker species

Black-backed and northern three-toed woodpeckers were also present in unburned spruce-fir forest (UI and UII) adjacent to the Waterfalls Canyon burn in low but somewhat higher densities than recorded by Salt (1957) for a different spruce-fir stand in Grand Teton National Park (2.0 versus 0.7 pairs/100 acres). Although the difference is small and perhaps insignificant considering the high variance charact-eristic of bird censuses, some three-toed woodpeckers may have ranged into unburned spruce-fir from nearby burned sites where these species were relatively common the first few years following fire.

Hairy woodpeckers were present in burned areas until forest canopy closure about 40 years post-fire. They were also present in the oldest unburned areas, but at much lower densities than in younger post-fire areas. Nest holes excavated by these three woodpecker species and by the less abundant common flicker are important to secondary cavity nesters such as mountain bluebirds and tree swallows. Nest holes in fire-killed snags are extremely important to these latter two species, which make up 29-64% of the total breeding birds in the 5-29 year post-fire areas. Loss of fire-killed snags combined with forest canopy closure causes tree swallow and mountain bluebird populations to disappear by about 50 years post-fire.

White-crowned sparrows, which are usually associated with shrublands, were present only in the 25 year post-fire stand where lodgepole pine were 7-8 feet (2.1-2.4 m) tall. Four years later when the trees were 10-11 feet (3.0-3.3 m) tall and stand appearance had changed from shrubland to young forest, white-crowned sparrows were absent, and they were not recorded in any older stands.

In our study areas Clark's nutcrackers and Cassin's finches were relatively important before forest canopy closure at about 40 years, but not thereafter (Table 2). In contrast Salt (1957) found rather high densities of Clark's nutcrackers in older stands of lodgepole pine, lodgepole pine-spruce-fir, and spruce-fir (1.7, 11.7, and 20.3 pairs/100 acres, respectively) in Grand Teton. Reasons for these differ-ences are unknown but young may have fledged and adults may have left by the time of our censuses. Clark's nutcrackers nest in March and brood for 22 days in Yellowstone(Skinner 1929). However, Salt's and our censuses should have been similarly influenced since they probably were conducted about the same time of year. Clark's nutcrackers may be more ubiquitous and/or erratic in their distribution and movements relative to seral stages.

The Oregon junco, robin, yellow-rumped warbler, and the gray jay were ubiqui-tous in the various successional stages. Robins were present near openings created by small ponds in the oldest stands.

Species composition the first 3 years after the Waterfalls Canyon fire was similar in moderately burned and unburned spruce-fir with the major exception that northern and black-backed three-toed woodpeckers and hairy woodpeckers were more abundant on the moderate burn.

The western tanager, golden-crowned and ruby-crowned kinglets, red-breasted nuthatch, mountain chickadee, and yellow-rumped warbler were more abundant in moderately burned and unburned spruce-fir or spruce-fir-lodgepole pine than in

Table 2. Pairs of breeding birds/100 acres in seral vegetation following fire in coniferous forests of Yellowstone and Grand Teton National Parks.[@] Birds are listed in order of appearance and disappearance with time.

	Burn Intensity and Years Post-Fire																												
	Severe																			Moderate			Unburned						
																							UI[#]			UII[#]			
Species	1	2	3	5	7	11	13	17	25	29	43	44	45	57	61	111	115	300	304	1	2	3	A	B	C	A	B	C	
Northern Three-Toed	34	15	2																	7	10	5				2	2		
Black-Backed Three-Toed	5	+	2																	2	5	2		2					
Hairy Woodpecker		10	10	6	3	16	3	5	3	5	2								+	5	2	2	2		+	+			
Common Flicker			2	6	3				3		+	+													+				
Western Wood Pewee	+	5	15		+	+	+	+	+											5	2	+					+		
House Wren					3	8																							
Brown Creeper			+																	5	2	5	2			2			
Townsend's Solitaire					+																								
Tree Swallow		+		13	64	52	54	27	49	27		+									+								
Mountain Bluebird	+	15	19	19	54	24	61	22	32	45			+									+							
Clark's Nutcracker		+	+	20	22	4	18	12	3	+											+	+			+			2	
Cassin's Finch			19		8	4	3	12	8																				
Oregon Junco	10	17	12		24	+	38	47	35	35	2	10	5	8	5	2	10	4	4	12	19	17	10	15	10	2	10	10	
Robin	+	19	22	6	22	20	24	31	22	23		+	+	+		8	5	4	4	+	2	2	+	+	+	+	+	2	
Chipping Sparrow	+	5	7	6	3	+	3		11	9	39	27	17	2	5	2	+	+	4	19		17	10	7	5	2	+	10	
Ruby-Crowned Kinglet	+				3		3				+	+		6	5	6	10	4	24	2	+	+	12	24	7	2	2	5	
Mountain Chickadee	+	+	+	7	3			6		+	5	7	5	2	5	14	10	16	12	15	10	7	15	22	12	24	12	7	
Yellow-rumped Warbler		2	2	6		+	+	5	+	5	5	2	+		10		5	6	4	5	7	5	24	12	15	+	12	7	
Gray Jay	2			6		4	3		3	+	15	10	2	4	5	4	+	4	4	7	2		10	2		7	2	5	
Hermit Thrush							3							4	5	8	10	8	4			+							
Swainson's Thrush	+	+									+		+							19	10	5	10	7	5	12	7	15	
Pine Siskin	+	+	+	+								+		+	+	+		+		+	+	+	+	+	+	+	+	+	
Western Tanager		+	+									+								10	+	10	15	7	5	5	5	+	
Red-breasted Nuthatch						4														+	2	+	7	+	5	2	+	2	
Golden-Crowned Kinglet																				+	10	2	22	+	10	29	17	31	
Ruffed Grouse									+		2	+	+	+		+		+									2		
Pine Grosbeak											+			4		4		4					2						
White-Crowned Sparrow									32																				

Table 2. (Continued)

Species	Burn Intensity and Years Post-Fire: Severe																			Moderate			Unburned UI#				Unburned UII#		
	1	2	3	5	7	11	13	17	25	29	43	44	45	57	61	111	115	300	304	1	2	3	A	B	C	A	B	C
Common Nighthawk																												
Tree Sparrow**		+	+		+				+																			
Song Sparrow										+			+															
Williamson's Sapsucker										8																	+	
Yellow-bellied Sapsucker							21																					
Red Crossbill			+								+																	
											+	+	+							+	+	+	+	+	+	+	+	+
TOTAL Breeding Pairs	59	104	119	96	215	140	235	175	204	162	77	65	36	33	41	50	52	53	61	118	89	87	144	103	80	94	81	99
TOTAL Species On Site	12	6	18	11	15	13	14	11*	16*	13*	14*	14*	11	10	8	10	8	11	9	18	19	20	16	14	15	16	18	14

*A sandhill crane nested in the 25, 29, 43, 44, and Unit II, 2 areas; a great grey owl nested in the 17 year area.

**No evidence was found that this species was nesting.

@ "+" indicates presence on the area but not on the belt transect. One pair per 100 acres was assumed to be present.

UI and UII were censused three consecutive years A, B, C.

severely burned spruce-fir-lodgepole pine. Species composition on the moderate burn will probably approach that of the unburned sites relatively quickly. Within a few years the only noticeable remaining effects from the moderately intense fire will be a few scattered, fire-killed standing snags, charred fallen trees, and burned out stumps. Moderate fire will have done little more than thin the overstory and understory without altering plant species composition in a major way.

Breeding bird density 5-29 years post-fire was 52-76% higher than in closed canopy lodgepole pine stands 40 or more years post-fire and 39-66% higher than in unburned spruce-fir-lodgepole pine (UI) or unburned spruce-fir (UII). Closure of the forest canopy at about 40+ years is associated with a dramatic decline in total bird density which lasts until another severe fire occurs or for 300 or more years without severe fire (Fig. 1).

The Shannon-Weaver index of bird species diversity increased from 1.5 to 2.3 between 1 and 3 years post-fire on a severely burned site, then varied between 1.8 and 2.2 from 5-300 years post-fire (Fig. 2). Lowest diversity occurred 43-45 years post-fire when the forest canopy was closing. Diversity was slightly higher in unburned spruce-fir-lodgepole pine and spruce-fir (UI and UII) than in severely burned spruce-fir or lodgepole pine 5-304 years post-fire. Diversity was highest in moderately burned spruce-fir 1-3 years post-fire, primarily due to the post-fire increase of woodpeckers. As fire effects are mitigated by time and fire-influenced bird species drop out, bird diversity on the moderate burn will undoubtedly decline to approach that of unburned spruce-fir or spruce-fir-lodgepole pine.

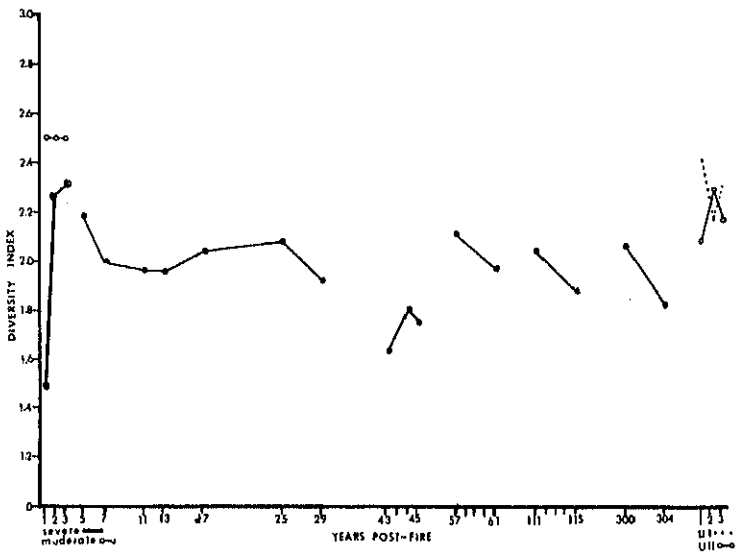

Fig. 2. Shannon-Weaver diversity index for breeding birds in seral vegetation following fire in coniferous forests of Yellowstone and Grand Teton National Parks. Unburned areas UI and UII were censused 3 consecutive years.

CHANGES IN SPECIES COMPOSITION AND BIOMASS BY FEEDING CATEGORY

Air-soaring species are present by the second year post-fire, become more firmly established by the fifth year, and drop out by the time the forest canopy closes 43-45 years post-fire (Table 3). Air-soaring species depend upon nest sites of timber-dwelling species, which are present from 1 year post-fire until the forest canopy closes and again in the oldest seral stages.

More ground-insect species usually were present in the more open vegetation prior to closure of the tree canopy about 40 years post-fire than subsequently; however, openings around small ponds in older stands harbored many ground-insect species.

More foliage-insect species and timber-searching species were present in the oldest seral stages and in moderately burned spruce-fir-lodgepole pine than in burned sites of any age, again showing the similarity between moderately burned and unburned spruce-fir forests.

Total breeding bird biomass was at least 70% greater 5-29 years post-fire than after 40 years post-fire when the forest canopy closed (Fig. 3). Biomass of air-soaring, air-perching, foliage-seed, timber-drilling, ground-insect, and ground-seed species was greater prior to canopy closure. Only foliage-insect and timber-searching species had greater biomass in unburned than burned areas. The higher biomass of foliage-seed species in burned than unburned stands was due to the Clark's nutcracker.

Biomass was similar in moderately burned and unburned spruce-fir for all feeding categories except timber-drillers. Their biomass was greater in the moderate burn due to woodpeckers.

Even though fire drastically changed forest vegetation, bird biomass equaled or exceeded pre-fire levels one year post-fire (Fig. 3). From 2-29 years post-fire, or until the forest canopy began to close, bird biomass was higher in burned than unburned areas. Although fire does change the forest and its associated bird fauna, closure of the forest canopy causes a greater and far longer lasting change in bird biomass.

GENERALIZED PATTERN OF AVIFAUNAL SUCCESSION

Immediately After Fire

Immediately after fire had swept through the severely burned study site within the Waterfalls Canyon Burn, hundreds of pine siskins occupied the tops of fire-killed trees apparently feeding on seeds released from cones. Feeding by pine siskins continued for at least three weeks post-fire. Cassin's finches, hairy woodpeckers, northern three-toed woodpeckers, western tanagers and robins were also present immediately after the fire, but pine siskins and Clark's nutcrackers were the most abundant species. Two western tanagers fed near flames and Clark's nutcrackers fed on large wood-wasps (*Urocerus gigas flavicornus:* Siricidae) ovipositing in the bases of fire-killed trees the first 5 days after fire passed through.

Severe Burns 1-4 Years Post-fire

Prodigious numbers of roundheaded borers (*Monochamus* spp. and *Xylotrechus longitarsis:* Cerambycidae) were under the bark of fire-killed trees on the Waterfalls Canyon Burn 1 year post-fire. The borer's noisy chewing was one of the more prominent sounds throughout the burn. Northern three-toed woodpeckers and

Table 3. Number of species in feeding categories in post-fire areas.

Feeding Category	Burn Intensity and Years Post Fire: Severe																			Moderate			Unburned UI**			Unburned UII**		
	1	2	3	5	7	11	13	17	25	29	43	44	45	57	61	111	115	300	304	1	2	3	A	B	C	A	B	C
Air-soaring	0	1	0	1	2	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Air-perching	1	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0
Timber-searching	1	1	2	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	3	3	3	3	2	2	3	2	2
Timber-drilling	2	3	3	1	1	1	2	1	1	1	2	0	0	0	0	0	0	0	1	3	3	3	1	1	1	2	1	0
Foliage-seed	2	2	3	3	2	2	2	1	2	2	3	3	2	3	2	3	1	3	1	3	4	3	4	3	3	3	3	4
Foliage-insect	1	2	2	1	2	2	2	1	1	1	2	3	1	1	2	1	2	2	2	4	4	4	4	4	4	4	4	4
Ground-seed	1	2	3	0	2	2	2	2	3	3	1	1	4	1	1	1	3	1	3	1	1	1	3	3	3	3	4	3
Ground-insect	4	4	4	4	5	3	4	2	6	3	4	4	3	4	2	4	1	4	1	3	2	5	1	1	2	1	2	1
TOTAL	12	16	18	11	15	13	14	10*	15*	12*	13*	13*	11	10	8	10	8	11	9	18	19	20	16	14	15	16	17*	14

*A sandhill crane nested in 25, 29, 43, 44 and Unit II areas; a great grey owl nested in the 17 year area.

**UI and UII were censused three consecutive years as indicated in columns A, B, and C, following the Waterfalls Canyon fires in Grand Teton Park.

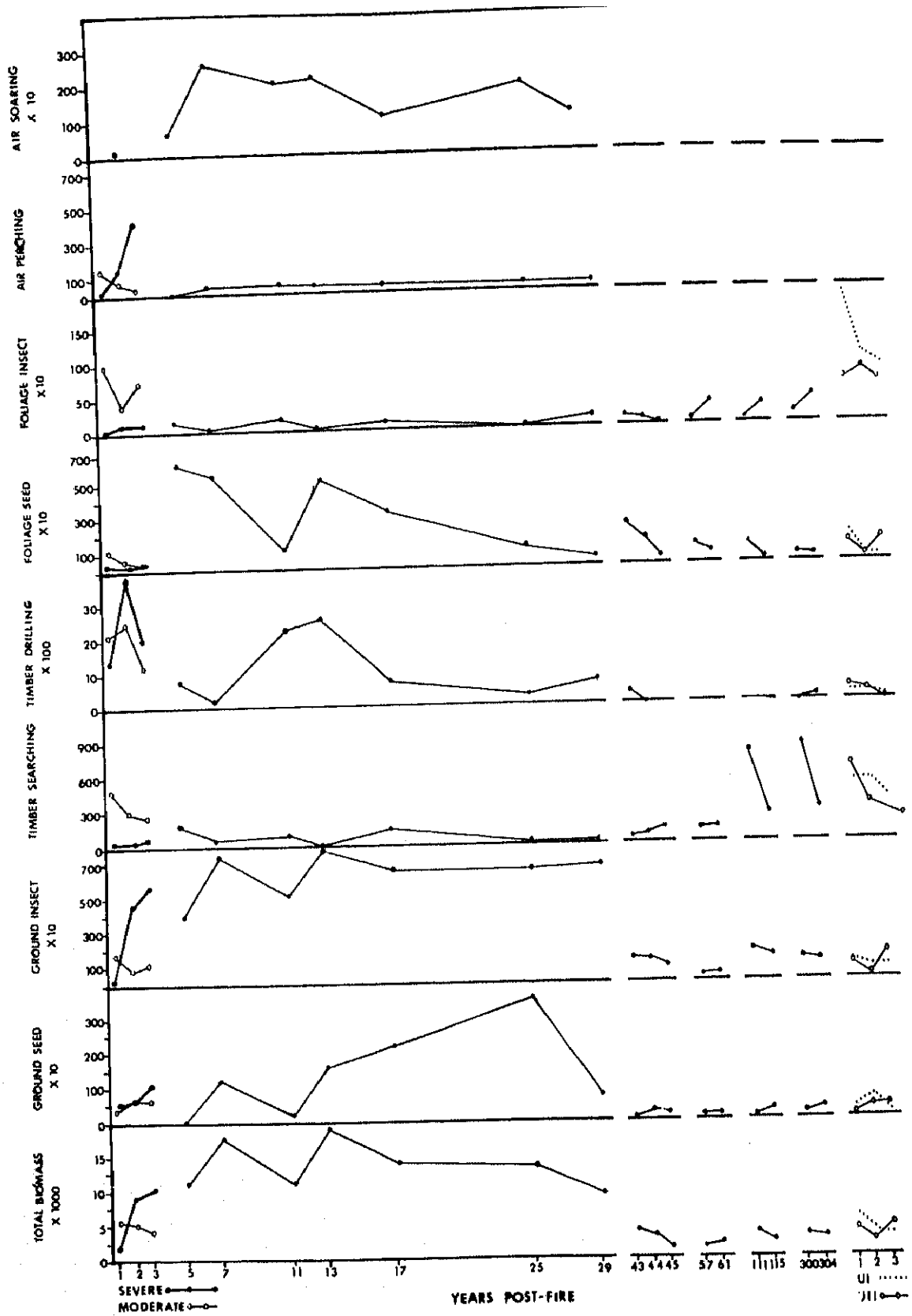

Fig. 3. Biomass (grams) of breeding birds in feeding categories in seral vegetation following fire in coniferous forests of Yellowstone and Grand Teton National Parks. Unburned areas UI and UII were censused for 3 consecutive years.

ack-backed three-toed woodpeckers were attracted to feed extensively on these rers. One woodpecker captured seven borers per minute during a five minute period. iiry woodpeckers became established the first or second year post-fire, but at a wer density than the two three-toed woodpecker species.

By two years post-fire, roundheaded wood borer populations declined. Their ctivity helped loosen the bark on snags, and the bark began to fall off, and the ice fire-blackened trees began to bleach white or grey. Populations of three-toed oodpeckers declined precipitously, but hairy woodpeckers persisted.

Three-toed woodpeckers and hairy woodpeckers start a "tree hole nest cycle" n standing, fire-killed trees (Taylor 1979). Mountain bluebirds, tree swallows, nd other birds nest in woodpecker nest holes.

The western wood pewee, Clark's nutcracker, Cassin's finch, Oregon junco, robin, hipping sparrow, mountain chickadee, yellow-rumped warbler, Swainson's and/or ermit thrushes, and pine siskin nest and/or feed on newly burned areas.

evere Burns 5-25 Years Post-fire

Two major changes occur during this period. Three-toed woodpeckers are lost, pparently due to reduced or absent food supply, and the number of secondary cavity esting species increases. Tree swallow and mountain bluebird densities depend upon the number of standing snags with nest cavities. Standing snags gradually decrease lue to rotting off at the base and from windfall during spring when melting snow soaks the soil. By 25 years post-fire lodgepole pines will be 7-8 feet (2.1-2.4 m) tall, and the area will look like shrubland. White-crowned sparrows will be relatively abundant.

Severe Burns 25-30 Years Post-fire

Trees will be 10-11 feet (3.1-3.4 m) tall. Appearance of the area changes from shrubland to young forest. White-crowned sparrows disappear. Mountain bluebirds and tree swallows may decline, depending upon rate of loss of standing snags with nest cavities. Other species present 1-4 years post-fire persist.

Severe Burns 30-50 Years Post-fire

The forest canopy closes as trees grow taller, spread out, and shade the ground. Only a few standing snags remain by 50 years post-fire. Closure of the canopy is the most important event in post-fire bird succession. Though it occurs gradually, canopy closure is associated with a 62-82% decrease in total breeding pairs compared to earlier seral stages, mostly due to loss of tree swallows and mountain bluebirds, but also to lower densities of almost all other species present earlier. Chipping sparrows reach their peak density during this period and become a major component of the avifauna. Other common species include the robin, Oregon junco, mountain chickadee, yellow-rumped warbler, ruby-crowned kinglet, hermit and Swainson's thrushes, pine grosbeak, ruffed grouse, red crossbill, and pine siskin.

Severe Burns 50-100 Years Post-fire

This is a period of stagnation. Species are fewer and densities are lower than one year post-fire. A major influence on species diversity is the number of small ponds or other openings around which robins, Oregon juncos, and chipping sparrows concentrate. The ruby-crowned kinglet, mountain chickadee, gray jay, pine grosbeak, hermit and Swainson's thrushes, and ruffed grouse are common, but also occur in other seral stages.

Severe Burns 100-300 Years Post-fire

As the lifespan of lodgepole pine is completed, the trees breakup, die, and/or are toppled by wind. The forest will be opened up compared to 100 years post-fire. No new bird species occur, however. Bird densities remain low compared to early post-fire seral stages.

Spruce-Fir Forest

Assuming succession proceeds without major perturbation to the spruce-fir forest, species dominance shifts to foliage-insect and timber-searching species. The golden-crowned kinglet and the red-breasted nuthatch are new species not consistently present in earlier seral stages. The brown creeper, mountain chickadee, and red-breasted nuthatch are common timber-searching species. Foliage-insect species include the ruby-crowned kinglet, yellow-rumped warbler, western tanager, and golden-crowned kinglet. Other species such as the robin, Oregon junco, chipping sparrow, gray jay, Swainson's thrush, pine siskin, and red crossbill are also present.

Moderate Burns

For the first few years post-fire, the avifauna of moderately burned coniferous forests consists of species characteristic of both severely burned forests (northern and black-backed three-toed woodpeckers and western wood pewee) and unburned forests (ruby- and golden-crowned kinglets, mountain chickadee, yellow-rumped warbler, Swainson's thrush, red-breasted nuthatch, and western tanager).

As early post-fire effects decrease due to new herb and shrub growth, and as fire-killed trees topple or are masked by growth of other trees, fire impacts on avifauna decrease. Within about 10 years post-fire, a moderately burned area loses almost all resemblance to a burned forest.

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APPENDIX 1

SPECIES	FEEDING CATEGORY[1]
Northern three-toed woodpecker *(Picoides tridactylus)*	timber-drilling
Black-backed three-toed woodpecker *(Picoides arcticus)*	timber-drilling
Hairy woodpecker *(Picoides villosus)*	timber-drilling
Common flicker *(Colaptes auratus)*	ground-insect
Western wood pewee *(Contopus sordidulus)*	air-perching
House wren *(Troglodytes aedon)*	foliage-insect
Brown creeper *(Certhia familiaris)*	timber-searching
Townsend's solitare *(Myadestes townsendi)*	ground-insect
Tree swallow *(Iridoprocne bicolor)*	air-soaring
Mountain bluebird *(Sialia currucoides)*	ground-insect
Clark's nutcracker *(Nucifraga columbiana)*	foliage-seed
Cassin's finch *(Carpodacus cassinii)*	ground-seed
Oregon junco *(Junco hyemalis oreganus)*	ground-seed
American robin *(Turdus migratorius)*	ground-insect
Chipping sparrow *(Spizella passerina)*	ground-insect
Ruby-crowned kinglet *(Regulus calendula)*	foliage-insect
Mountain chickadee *(Parus gambeli)*	timber-searching
Yellow-rumped warbler *(Dendroica coronata)*	foliage-insect
Gray jay *(Perisoreus canadensis)*	foliage-seed
Hermit thrush *(Catharus guttatus)*	ground-insect
Swainson's thrush *(Catharus ustulatus)*	ground-insect
Pine siskin *(Carduelis pinus)*	foliage-seed
Western tanager *(Piranga ludoviciana)*	foliage-insect
Red-breasted nuthatch *(Sitta canadensis)*	timber-searching
Golden-crowned kinglet *(Regulus satrapa)*	foliage-insect
Ruffed grouse *(Bonasa umbellus)*	ground-insect

Pine grosbeak *(Pinicola enucleator)*	foliage-seed
White-crowned sparrow *(Zonotrichia leucophrys)*	ground-seed
Common nighthawk *(Chordeiles minor)*	air-soaring
Tree sparrow *(Spizella arborea)*	ground-seed
Song sparrow *(Melospiza melodia)*	ground-seed
Williamson's sapsucker *(Sphyrapicus thyroideus)*	timber-drilling
Yellow-bellied sapsucker *(Sphyrapicus varius)*	timber-drilling
Red crossbill *(Loxia curvirostra)*	foliage-drilling
Great gray owl *(Strix nebulosa)*	
Sandhill crane *(Grus canadensis)*	

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[1]From Salt (1957)

Extending over large areas of Arizona, Colorado, Nevada, New Mexico, and Utah it occupies somewhere between 43 and 76 million acres of land in the West. In New Mexico alone the woodland covers over 32,000 square miles or 26 percent of the state (Pieper 1977). The woodland stretches from the east slope of the Sierras to Oklahoma and from Oregon to Texas and into Mexico. It is the common vegetation-type of the foothills, low mountains, escarpments, and mesas of the southwest (Fig. 1). Throughout its range this "pygmy forest" shows broad tolerance limits ranging in elevation from a high of 10,000 ft. in the Sierras to a low of 3200 ft. in the four corners area, with junipers alone extending even lower in many areas (West et al. 1975). It is found on a variety of soils derived from granite, basalt, limestone, and mixed alluvium (Hurst 1975).

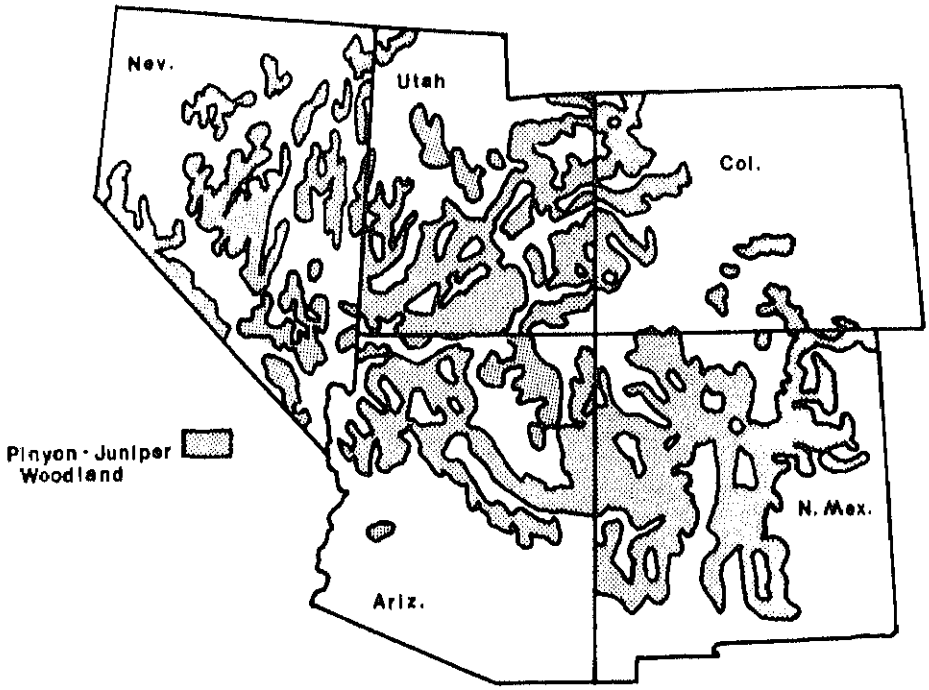

Figure 1. The distribution of pinyon-juniper woodland in the five western states where it is most abundant (From Clary 1975).

The major trees of this woodland consist of four species of junipers, Juniperus occidentalis, J. deppeana, J. monosperma and J. osteosperma. The latter species is the most wide-spread of the junipers. The two most common pinyon pines are Pinus monophylla and P. edulis with the latter species having the most extensive distribution. The dominant trees of the area are relatively small (hence the name pygmy forest) ranging in height from 15-40 ft. with individual trees having dense foliage. In general the junipers are more drought-resistant than pinyon pines and therefore occur in highest densities at lower elevations, whereas, pinyon pines become more abundant at higher elevations in this woodland (Short and

McCullock 1977). The density of these trees varies from very sparse to very dense depending on elevation, climate, and soil type. Total plant cover increases with elevation up to about 6600 ft. (Tueller et al. 1979).

The understory vegetation of the pinyon-juniper woodland is highly variable depending on soil type, exposure, and climatic pattern. Tueller et al. (1979) lists 240 positively identified species of vascular plants from the Great Basin pinyon-juniper woodlands. The list includes 67 species of shrubs and succulents, 46 grasses, and 122 forbs that grow under pinyon and juniper trees. Major shrubs include sagebrush (Artemisia sp.), bitterbrush (Purshia tridentata), rabbitbrush (Chrysothamnus sp.), and various species of oaks (Quercus spp.). Few of these species are found growing in association with one another, as the understory is reasonably depaupered. None of the shrubs, succulents, grasses or forbs are listed as rare and endangered and none are restricted to this vegetation type. Most woodlands contain only a few of these species. Thus, plant species diversity (as well as density) is reasonably low compared to other vegetation types in the southwest.

The climate of this vegetation-type can be summarized as being rather severe with hot summers, cold winters, low amounts of precipitation in the form of rain and snow, low relative humidity and high winds. Mean daily maximum temperatures for the hottest month of the year vary from 26°C to 36°C. Total yearly precipitation varies between 8 and 18 inches (West et al. 1975).

The lower limits of this woodland now mingle with grassland, desert scrub, Great Basin Desert or shrublands in different parts of its range. Because of climatic cycles (cool, moist to hot, dry) this lower boundary has been very active during the last 10,000 years (Martin and Mehringer 1964, Wright et al. 1973, Wells and Berger 1967). Evidence from pollen deposits, sloth dung, and wood rat middens indicate a considerable lowering of this boundary. This depression caused isolated areas of the woodland to come into contact with other such areas thus increasing the potential for redistribution of the flora and fauna. The return of a warmer, drier climate caused an upward retreat leaving behind isolated relict pockets of pinyon-juniper woodland, with its faunal components.

Even though early settlers heavily used pinyons and junipers for mine props, fence posts, and fuel, during the last 130 years the vegetation type is undergoing an expansion into low shrublands, grasslands and Great Basin Deserts (West et al. 1975). At the same time the density of trees in more permanent stands is also increasing. Numerous causes have been proposed to explain this increase, but the major culprit seems to be overgrazing by cattle and sheep (Aro 1971). Improper grazing has reduced forage production thereby releasing the trees from competition with the herbs and shrubs. Johnsen (1962) believes the spread of juniper in northern Arizona is due to the increased spread of seeds by livestock, lack of periodic fire, overgrazing which reduces competition of grasses with juniper seedlings, and a gradually changing climate which favors the spread of juniper. La Marche (1974) presents evidence that the period from 1850 to 1940 was wetter and warmer than the period before or after this.

It is evident that this woodland as a whole is an extremely complex, variable community. As stated by West et al. (1975), "Early attempts to explain distribution, composition, successional changes, and management responses in terms of single factors were overly simplistic. These variations can be better explained in terms of a complex of environmental patterns, historical events, and successional mechanisms. The relative importance of each factor of the environmental complex varies with the synecological context."

A major characteristic of this woodland as far as birds are concerned is the periodic production of vast quantities of pinyon pine seeds and juniper berries. Large crops of pine seeds are produced once every five or six years whereas juniper berry production occurs every two to three years. In many years neither tree forms reproductive propagules. Both life-forms appear to have intra-specific synchrony. For example, in a year of a good berry crop, one hectare contains between 19 and 38 million berries. A cubic meter of foliage holds 20,000 berries. The number declines steadily through the late fall and winter as birds and mammals consume them. The flesh of a single berry has about 315 calories making it a desirable source of energy. The berries are a shiny blue in color making them conspicuous; they ripen in the fall when insects are sparse and bird densities are high due to migration (Salomonson 1978). Thus junipers have adaptations favoring zoochory (Morton 1973). The pinyon pine also has a constellation of adaptations that favor dispersal by animals, especially birds (Table 1) (Vander Wall and Balda 1977). This pine not only allows animals easy access to its seeds but may entice dispersal agents. This means the seeds are easily located, extracted from the cones and eaten or cached for future use (Vander Wall and Balda 1977, Ligon 1978). More *Pinus edulis* seeds are cached in dry, exposed soils than can be used by the birds in years of high cone crops. In some years, pinyon pines produce absolutely no cones per hectare (Balda, unpubl. data), whereas in other years they may produce as many as 1800 cones/tree (Ligon 1971). These seeds are extremely nutritious, containing about 7400 cal/g (Little 1938).A pinyon pine seed contains 14.5 percent protein, 60 percent fat, and 18.7 percent carbohydrate (Botkin and Shires 1948). The large size, high energy content, and high protein level makes this seed a highly desirable food stuff.

Management of pinyon-juniper woodlands since the mid-40's has largely consisted of control of the spread of junipers (and in some cases pinyon) into grasslands and type-conversion of pinyon-juniper woodlands into grazing lands. Both eradication of the type and control has been justified on public lands because the trees are generally considered as of low commercial value relative to other harvestable trees of the West. During the period 1950 to 1964 Box et al. (1966) estimate that approximately three million acres of pinyon-juniper woodland were converted to grazing lands. Between 1950 and 1961 more than one million acres were converted in Arizona a 1964).

The major objective of most type-conversion referred to as "Range Improvement Projects" is t forage for livestock (Terrel and Spillett 1975). represent "a change from multiple use to one use 1977). Land managers today are going through a

soul-searching about how to proceed with management on these lands. This treatment has not been popular, leaves the area an aesthetic disaster has questionably proven long range benefits and "Most questions concerning wildlife and pinyon-juniper range conversion are unanswered and probably will remain so." (Terrel and Spillett 1975). The best synopsis of pinyon-juniper management and guidelines for future use can be found in a symposium edited by Gifford and Busby (1975).

TABLE 1. Features of pines with different dispersal strategies

Characteristic	*P. ponderosa* (wind)	*P. edulis* (animal)
Seed size	small	large
Seed conspicuous	no	yes
Seed quickly released	yes	no
Seed coat labelled	no	yes
Synchronous cone opening	yes	no
Position of cone	down, out	up, out
Cone scales	present	absent

BREEDING BIRDS

A total of 73 different species of birds are reported to breed in pinyon-juniper woodlands (Table 2). Undoubtedly more records are known but these will most often be rare or unusual occurrences. These 73 species are taxonomically aligned in 8 orders and 25 families. Because of the geographic area span by this plant community and the wide physiognomic variety (over its range), no one area contains near this breeding diversity. For example, in north-central Arizona 5 pinyon-juniper plots were sampled intensively during two breeding seasons (Grue 1977, Masters 1979) and the number of breeding species per 40 ha plot ranged from 12 to 24 and averaged 19 species. Rasmussen (1941) reports 43 species inhabiting the pinyon-juniper woodland on the Kaibab Plateau in summer but has good evidence for breeding by only 12 species. Hardy (1945) lists 22 species as regular breeders in Utah pinyon-juniper woodlands whereas Hering (1957) reports 16 breeding species.

TABLE 2. Breeding birds of pinyon-juniper woodlands[1)]

Species	Status[2)]	Distribution[3)]	Niche Width[4)]
Turkey Vulture	S	4	
Cooper's Hawk	P	2	
Red-tailed Hawk	P	4	
Swainson's Hawk	S	1	
Ferruginous Hawk	P	2	
Golden Eagle	P	3 (Sp.)	
Prairie Falcon	P	2 (Sp.)	
American Kestrel	P-S	4	
Gambel's Quail	P	2	
Mourning Dove	P-S	7	
Screech Owl	P	3	obligatory
Great Horned Owl	P	3	
Long-eared Owl	S	1	
Saw-whet Owl	P	1	
Poor-will	S	2	
Common Nighthawk	S	3	
Lesser Nighthawk	S	2	
White-throated Swift	S	2 (Sp.)	
Black-chinned Hummingbird	S	4	semi-obligatory
Costa's Hummingbird	S	1	
Broad-tailed Hummingbird	S	3	
Common (red-shafted) Flicker	P	6	
Hairy Woodpecker	P	4	
Ladder-backed Woodpecker	P	1	
Western Kingbird	S	1	
Cassin's Kingbird	S	2	
Ash-throated Flycatcher	S	7	semi-obligatory
Say's Phoebe	S	2	
Gray Flycatcher	S	2	obligatory
Western Wood Pewee	S	1	
Violet-green Swallow	S	2	
Cliff Swallow	S	1 (Sp.)	
Scrub Jay	P	6	obligatory
Black-billed Magpie	P	2	
Common Raven	P	6	
Piñon Jay	P	5	semi-obligatory
Mountain Chickadee	P	3	
Plain Titmouse	P	7	obligatory
Bushtit	P	6	semi-obligatory
White-breasted Nuthatch	P	3	
House Wren	S	1	
Bewick's Wren	P-S	3	semi-obligatory
Cañon Wren	P-S	3 (Sp.)	
Rock Wren	P-S	4	
Mockingbird	S	4	semi-obligatory
American Robin	P-S	1	
Western Bluebird	P-S	1	
Mountain Bluebird	P-S	4	
Blue-gray Gnatcatcher	S	5	semi-obligatory
Loggerhead Shrike	S	2	

TABLE 2. (cont.)

Species	Status[2]	Distribution[3]	Niche Width[4]
Gray Vireo	S	3	obligatory
Solitary Vireo	S	2	
Black-throated Gray Warbler	S	5	semi-obligatory
Scott's Oriole	S	3	
Brown-headed Cowbird	S	4	
Hepatic Tanager	S	1	
Black-headed Grosbeak	S	5	
Lazuli Bunting	S	2	
Cassin's Finch	S	1	
House Finch	P-S	5	semi-obligatory
Lesser Goldfinch	S	2	
Red Crossbill	S	1	
Green-tailed Towhee	S	2	
Rufous-sided Towhee	P	6	semi-obligatory
Brown Towhee	P	2	semi-obligatory
Vesper Sparrow	P-S	2	
Lark Sparrow	S	4	semi-obligatory
Black-throated Sparrow	P-S	3	
Sage Sparrow	S	1	
Dark-eyed Junco	S	1	
Gray-headed Junco	P-S	1	
Chipping Sparrow	P-S	6	
Brewer's Sparrow	S	1	
Black-chinned Sparrow	P	2	semi-obligatory
Total: n = 74	P = 23 (32%) S = 38 (51%) P-S = 13 (17%)	S-O = 13 O = 5	

1) Data from Rasmussen (1941), Hardy (1945), Miller (1946), Hering (1957), Grue (1977), Masters (1979)
2) P = permanent resident; S = summer resident
3) The number indicates the number of census plots or study areas used
breeding. The maximum is 7. Sp. = special landscape required.
ory = in a given geographic area the species breeds only in
-juniper woodland; semi-obligatory = same as above but
ne additional plant community.

few, if any other natural habitat-types in North America have so few truly obligatory species. The reason(s) such should be the case is not clear but may relate to the great physiognomic diversity found in the pinyon-juniper woodland. Just as there is no typical pinyon-juniper woodland there are few obligate pinyon-juniper birds.

Just as the number of breeding species varies between woodlands so does breeding bird density. In southwestern Arizona where many oaks are found in the woodlands breeding bird density may reach 250 pairs per 40 ha (Balda 1967). This density is seldom if ever reached in the pinyon-juniper woodland where densities vary between 30 and 190 pairs

per 40 ha (Table 3). Ninety-five pairs is about an average figure. Grasslands usually have fewer breeding pairs and ponderosa pine forests more than the pinyon-juniper woodland.

TABLE 3. Characteristics of the avian woodland breeding birds

Study	Habitat	No. of Breeding Species	No. of Breeding Pairs/40 ha
Balda, 1967	oak-juniper	36	224
Balda, 1967	oak-juniper-pine	36	267
Grue, 1977	juniper-parkland	17-23	54-179
Beatty, 1978	juniper-grassland	11-12	35-40
Grue, 1977	juniper-pinyon	24-26	66-130
Masters, 1979	pinyon-juniper I	9-10	90-87
Masters, 1979	pinyon-juniper II	18-21	191-138
Masters, 1979	pinyon-juniper III	19-19	122-133
Hering, 1957	pinyon-juniper (?)	15	33
Beidleman, 1960	pinyon-juniper	2	30
Hardy, 1945	pinyon-juniper	22	--
Miller, 1946	pinyon dominated	55	--

Breeding bird densities in a single location show rather large annual fluctuations that appear to be linked to biotic and physical factors. In very dry years the breeding bird populations may be reduced between 50 and 70% (Grue 1977). Possibly pinyon pine seed crops may attract breeding birds the next spring. Masters (1979) found a 28% increase in populations after a large cone crop (Table 4).

Table 4. Changes in breeding bird densities (pairs/40 ha) and diversities between years

Study	First Year Density/Diversity	Second Year Density/Diversity	%Change	Reason
Masters, 1979	191/21	138/18	28/14	Pinon seed crop before first year
Grue, 1977	130/26	66/24	49/8	Annual fluctuation in precipitation
Grue, 1977	179/23	54/17	70/26	Same as above

Masters (1979) attempted to explain the relationship between various habitat parameters and characteristics of the breeding bird

fauna. At the level of the community, she found that the number of breeding bird species was significantly correlated with a) the densit of pinyon pine, b) total tree density and c) pinyon pine foliage volume. Foliage height diversity (as measured in two-meter height classes) was a significant predictor of bird species diversity. Breeding bird density was significantly correlated with pinyon pine density when the bird population figures following a large pinyon pine cone crop are ignored.

A "typical avifauna" of the pinyon-juniper woodland thus appears t be as simplistic an approach as trying to describe a typical vegetatio for this woodland type. Never-the-less we have selected from the list of 74 breeding species a group that has a distribution score (Table 2) of four or higher and/or is listed as obligatory or semi-obligatory in niche width. A major danger here is that two closely related species may be sympatric and thus neither would have achieved the criteria for inclusion. Such could have been the case for nighthawks, kingbirds, hummingbirds, bluebirds, medium-billed sparrows and a few other cases. In these instances the most common of the dyad or triad was added to the list to make it as representative as possible. From Table 2, 29 species met the first criteria and the nighthawk and kingbird were added for reasons given above.

Resident Status

Of the 31 species that fit our "typical avifauna" criteria 14 (45%) are summer residents and 11 (35%) are permanent residents. Six species show variable patterns of residency either based on geographic considerations (i.e. summer residents in the northern portion of their range and permanent residents in the more southern areas) or variable weather conditions (i.e. migrate in harsh winter, remain stationary in mild winters). Hardy (1945) in eastern Utah described 36% of the nesting species as permanent residents and 64% as summer residents, almost identical to our typical avifauna if one includes the "switchers in the summer category.

Data from intensively censused plots in central Arizona over a two year period showed about the same split as does the Utah data (Grue 1977). The proportion of permanent resident species ranged from 35 to 40%.

In north-central Arizona however, Masters (1979) censusing three pinyon-juniper plots for two years found a range of permanent resident breeders from 32 to 56% (Table 5), and Hering (1957) near Mesa Verde, Colorado had 53% permanent residents. One could expect permanent residency to increase in the woodlands with decreasing latitudes but such an increase is not apparent from either the proportion of the breeding population that is permanent or the absolute number of species that do so. On both of Masters' (1979) plots with proportion of permanent residence above 50% the ratio of pinyon to juniper trees was better than 2:1. (Hardy's 1945 ratio was 0.36 to 1). Hering (1957) did not provide the necessary data to assess this habitat feature but the general area of her study contains high densities of P. edulis (pers. obs. R. P. Balda). Of the 55 species of breeding birds (a woodland high!) listed by Miller (1946) in a southern California woodland predominated by pinyon pine, 27 species or 49% were apparently permanent residents. Two areas without pinyons had 33 and 35%

permanent resident breeders. Thus, we suggest with caution that a positive correlation may exist between the proportion of permanent residents in the community and the proportion of trees in the woodland that are pinyon pines. In all probability no one factor will answer the question, but this one does deserve future investigation. Of the 18 species listed as either obligatory or semi-obligatory in this woodland 8 are permanent residents.

Table 5. Residence status of breeding birds from specific sites in north-central Arizona (Masters 1979)

Status	Number of Species (%) Sites I		II		III	
Permanent Resident	3.0*	(32)	8.0	(53)	7.5	(56)
Summer Resident	6.5	(68)	7.0	(47)	6.0	(44)

* 2 yr. average

Foraging Guilds

An instructive way to look at avian communities is the use of foraging guilds (Root 1967). A guild is defined as one or more species in a community that use similar foraging techniques. Guilds can be defined as broadly or narrowly as the observations and data base permit. Here for the sake of simplicity and accuracy (but sacrificing specifics) I define foraging guilds only by substrate-type. This is done because very little information is known about the species under consideration to allow for finer distinctions. Foraging guilds used include ground, foliage, air, bark, and flowers. If a species used two of these substrates I assigned half the value to each guild.

The descriptive analysis from nine different intensively studied woodland sites shows few trends. The number of ground foragers varied from 6 (Hering 1957) to 16 (Grue 1977) species. Relative proportions of ground foragers varied between 40% (Hering 1957) and 57% (Grue 1977). No significant correlation (Spearman Rank Correlation) between the density of pinyon pine or juniper and either the number or proportion of ground foraging species was found.

The number of foliage foragers in the breeding community varied from a low of three in a juniper-grassland (Beatty 1978) to a high of 12 in a predominantly pinyon pine stand. The mean number of species that used foliage as a substrate where both pinyon and junipers were represented was 5. The number or proportion of foliage foraging species showed no significant correlation with pinyon or juniper density.

The number of species of hummingbirds (nectar feeders) also shows no correlation with tree species density. Hummingbirds most likely respond more to the species composition and flowering patterns of the shrub and forb strata which may be limited by physical factors (temperature, moisture, etc.).

There is also no trend for aerial feeders. Aerial foraging species number between 1 (Hering 1957) and 9 (Miller 1946). On areas containing both pinyon and junipers the mean number of aerial feeders was 4.

In some woodlands a small group of breeding species forage extensively on trunks and large branches. In no intensive study area analyzed for this report where the ratio of pinyon to junipers was less than 1:1 did any of these species breed. Where pinyons outnumbered junipers by 2:1 or better two species appeared. Almost invariably these two species were the Hairy Woodpecker and White-breasted Nuthatch. The former species obtains insects by hammering holes through the bark or flaking layers of bark off in small plates. The latter species probes the crevices in the bark to obtain insects. Both species reach higher densities in ponderosa pine forests (Szaro and Balda 1979) than in the woodlands. Either there are more insects in, under, and on pinyon pine bark than juniper or the bark pattern is such that insects are easily extracted.

The "typical avifauna" for pinyon-juniper woodlands has a slightly higher number of ground and foliage foragers than the studies described above (Table 6). This probably occurred because our selected sample of birds is slightly larger than would be found in any one woodland area.

Table 6. Foraging Guilds for a "typical pinyon-juniper woodland"

Guild	*Number of Breeding Species (%)
Ground	14.5 (52)
Foliage	7.0 (24)
Aerial	4.5 (16)
Bark	1.0 (4)
Flower	1.0 (4)

*Carnivores not included

The above analysis has dealt solely with numbers of species because of the high year-to-year variability in densities. Master's (1979) regression models to predict characteristics of the bird populations included foraging guilds. Eight independent foliage variables were used. Pinyon density was significantly correlated with densities of aerial feeders, bark feeders, and total density of all insectivorous birds (Table 7). No variable contributed solely by junipers was important as a predictor of any of the breeding bird characteristics measured. Why the above result should occur is not immediately obvious but suggests pinyon pine may provide a more suitable foraging substrate than juniper.

Only fragmentary data exists to support the contention that juniper is less attractive as a foraging substrate than is pinyon pine. In an oak-juniper-pine (*Pinus cembroides* and *P. leiophylla*) woodland in southeastern Arizona, Balda (1969) studied foliage use by the 36 breeding species. The number of observations in each tree species were compared to the foliage volume contributed by each tree species. Based on foliage volume an expected number of bird observations per tree species was calculated. Actual foraging

observations in juniper were far less than expected, whereas foraging observations in pines were much greater than expected. At that time Balda proposed that the breeding birds may simply have not yet learned to use juniper as it is known that juniper is presently spreading into new areas and increasing in areas where it was once sparse. The Black-throated Gray Warbler, Chipping Sparrow, Bridled Titmouse and Common Bushtit utilized juniper more than any other species. Three of the four species listed above are members of our "typical woodland avifauna." In a pinyon-juniper-ponderosa pine ecotone Laudenslayer and Balda (1976) found that pinyon pine was selected more intensely than predicted by expected numbers generated from foliage volume. Juniper was selected approximately as often as expected. We explained this difference by using the relative proportion of foraging surface within both trees. Although both species have their green foliage concentrated on the outer edges of the branches, needles of pinyon pine are found growing farther inward than in juniper. Thus, if the growing areas and areas of green vegetation on these trees are used as prime foraging surfaces then pinyon provides more of this surface per tree than does juniper.

Table 7. Percent variability explained (r^2) of breeding bird parameters by vegetation factors which are significantly correlated (Masters 1979)

Factor	Density of Feeding Guilds		
	Aerial Feeders	Bark Feeders	Insectivores
Pinyon Pine Density	.980	.781	.949
Total Tree Density	.979	.776	.947
Pinyon Foliage Volume	.902	NS	.834

Insect densities in pinyons and junipers may also be a reason why pinyon density is a good predictor of density of insect eating birds. Masters (1979) found, however, that junipers had a higher number of insect taxa than did pinyon. Insect abundance (as measured by total length) was about the same in both trees. The similarity coefficient (a measure of community similarity) indicated that pinyon and juniper have different arthropod faunas associated with them.

Nesting Guilds

The classification of the avian community by nesting habits may also provide clues as to how breeding birds interact with the structure of the vegetation. Of the 31 species used as a "typical avifauna" 60% (18.5) nested in foliage (the 0.5 is for the Mourning Dove that uses both foliage and ground for a nest substrate), 23% (7) used cavities and the remainder nest on the ground. Hardy's data (1945) fits well with 61% of the breeding birds nesting in the foliage, 21% in cavities, and 18% of the species nesting on the ground.

On two intensively studied plots in central Arizona Grue (1977)

found an average of from 60 to 68% foliage nesting species in the breeding bird community. From 15 to 20% of the species nested in cavities. Again the fit is reasonable with what a "typical avifauna" would show (Table 8).

Table 8. Nesting guilds of breeding birds from specific sites in central Arizona (Grue 1977)

Nesting Guild	Number of Species (%) Pinyon-Juniper Woodland	Juniper Parkland
Foliage	16.5* (66)	14.0 (68)
Cavity	5.0 (20)	3.0 (15)
Ground	3.5 (14)	3.5 (17)
Total	25.0	20.5

* 2 yr. averages

In north-central Arizona Master's (1979) found cavity nesters to make up almost half of the breeding species on areas where pinyons outnumbered junipers (Table 9). Hering (1957) found cavity nesting species made up 47% of the breeding species on an area of presumable high pinyon densities. Both studies had 7 to 8 cavity nesting species present. The pinyon dominated woodland in California (Miller 1946) contained 11 cavity nesting species.

Table 9. Nesting guilds of breeding birds from specific sites in north-central Arizona (Masters 1979)

Nesting Guild	Number of Species (%) Sites I	II	III
Foliage	7.0* (74)	7.5 (50)	6.5 (48)
Cavity	2.0 (21)	7.0 (47)	6.5 (48)
Ground	0.5 (5)	0.5 (3)	0.5 (4)

* 2 yr. averages

The emerging pattern is more than suggestive that cavity nesting species will occur with higher probability in woodlands containing large numbers of pinyon pines. On three study sites in north-central Arizona Masters (1979) found that 79% of the variability (r^2) in density of the combined cavity nesting species (not species numbers as discussed above) was explained by the density of pinyon pines.

Both density and diversity of cavity nesting species may be related to pinyon pine in some manner. Since cavity nesters depend on weakened or diseased trees to excavate cavities in, it is possible that pinyon pine are more prone to attack by insects and other disease

causing organisms. Also, it may be that pinyon branches are more brittle and are therefore more prone to breaking thus allowing disease agents entry. Dead junipers are hard whereas dead pinyon pines contain soft wood (pers. obs.).

The question that remains deals with tree-type selection by the foliage breeding birds: Do foliage breeders select for either juniper or pinyon when choosing a nest site? Both Hardy (1945) and Short and McCulloch (1977) make unsubstantiated comments that foliage nesting birds prefer junipers over pinyons for nest-sites. Based on the amount of data presently available it is not possible to answer that question and more research is required to show if any preference is shown (Table 10). The two species that showed regular use of juniper were the Black-chinned Hummingbird and Black-throated Gray Warbler whereas the Chipping Sparrow showed no preference for either tree (Masters 1979, Balda 1969).

Table 10. Nest sites of foliage nesting birds in western woodlands

Study		Number of Nests in pinyon	juniper	other
Balda, 1967	oak-juniper 67 1	(not present)	1	12
Balda, 1967	juniper-oak-pine 46 46 29	--	11	10
Laudenslayer and Balda, 1976	pinyon-juniper-ponderosa pine 48 46 27	3	--	--
Masters, 1979	pinyon-juniper I 32 33	--	1	--
Masters, 1979	pinyon-juniper II 87 33	10	5	--
Masters, 1979	pinyon-juniper III 87 34	6	2	--

WINTERING BIRDS

Winter bird populations of the woodland have been studied in central Arizona by Grue (1977) and in north-central Arizona by Shrout (1977). A total of 32 species have been recorded as wintering in these woodlands. These 32 species belong to five orders and 14 families. Of these, 18 are permanent residents, 10 are winter residents, and 4 are switchers. The most regular winter residents are the two species of juncos, White-crowned Sparrow, and Ruby-crowned Kinglet. Three of these four species are seed eaters. Prominent "switcher" species are the Mourning Dove, American Robin, the two bluebirds, and the House Finch. Only the Bushtit, kinglet and wren are insectivorous (Table 11).

Species numbers vary considerably from year-to-year. Shrout (1977) reported a diversity of 10 species in one winter and 20 the next on the same 40 ha plot. Mean number of wintering species in Arizona woodlands is about 15 (Grue 1977, Shrout 1977).

Table 11. Birds wintering in pinyon-juniper woodlands

Species	Status*	Distribution (max = 3)
Rough-legged Hawk	W	1
Merlin	W	1
Prairie Falcon	P	(pers. obs.)
Gambel's Quail	P	1
Mourning Dove	P-S	2
Hairy Woodpecker	P	1
Common (red-shafted) Flicker	P	3
Horned Lark	P	1
Common Raven	P	3
Piñon Jay	P	1
Scrub Jay	P	3
Mountain Chickadee	P	1
Plain Titmouse	P	3
Common Bushtit	P	3
White-breasted Nuthatch	P	(pers. obs.)
Red-breasted Nuthatch	W	(pers. obs.)
Bewick's Wren	P	2
Ruby-crowned Kinglet	W	2
American Robin	P-S	1
Townsend's Solitaire	W	1
Western Bluebird	P-S	1
Mountain Bluebird	P-S	1
Sage Thrasher	W	1
Evening Grosbeak	W	1
House Finch	P-S	2
Cassin's Finch	W	(pers. obs.)
Rufous-sided Towhee	P	1
Vesper Sparrow	P	1
Dark-eyed Junco	W	3
Gray-headed Junco	W	3
Chipping Sparrow	P	3
White-crowned Sparrow	W	3
n = 32	P=16, W=11 and P-S=5	

Winter densities vary greatly from place-to-place and from year-to-year. For example during the winter of 1973-74 Grue (1977) reported 318 individuals per 40 ha in a pinyon-juniper woodland and 251 wintering birds in a 40 ha juniper parkland. This is a 21% difference.

Year-to-year variations are even more striking. In some years the woodland supports huge flocks (too large to count) of bluebirds, American Robins and mixed flocks of juncos. In other years one can walk for hours seeing only a very few birds (Vaughan pers. comm., R. P. Balda pers. obs.). Shrout (1977) found 293 wintering birds per 40 ha in the winter of 1973-74 and 75 individuals during the winter of 1974-75 on the same plot. Using a conservative calculation this is a 74% change in population density between years.

These fluctuations appear to be caused by a combination of physical and biotic factors. Open water appears to be critical to winter birds of this habitat-type. This may occur because most are feeding on tree, shrub, grass and forb seeds as water-bearing insects are rare. Large flocks of sparrows, jays, juncos, bluebirds and robins concentrate at different times of day at cattle watering tanks. In high density years flocks of robins have been seen by the authors flying kilometers to and from water holes. Heavy winter snows, however, cause a temporary movement to lower elevations (pers. obs.).

Heavy crops of juniper cones occur at irregular intervals but generally a heavy crop can be expected every two to five years (Tueller and Clark 1975). Shrout's (1977) data are for a year with a "bumper crop" of juniper cones and then for a year with no berry production. Large crops may be local or synchronized over relatively large areas. The "berry" crops ripen in the fall and attract large numbers of birds. Some birds such as the Cassin's Finch and Evening Grosbeak consume the pulpy flesh and seed whereas others such as the bluebirds, robins, and solitaires digest only the fleshy pulp and defecate the seeds (Salomonson 1978). Johnsen (1962) and Salomonson (1978) found that fresh, ripe seeds passed through the digestive tract of birds germinate faster than other seeds. Due to bird dispersal Salomonson (1978) found that most seedlings germinate and grow away from the source trees but most berries were found below the trees. In early fall most juniper seed eaters are highly nomadic in their search for large crops. Defecation by these birds during nomadic flights over grassland and other rangelands may be one of the causes for the encroachment of junipers into other habitat types.

Other birds respond differently to large juniper berry crops. Some Townsend's Solitaires (Salomonson 1978) and possibly some American Robins (T. A. Vaughan pers. obs.) set-up permanent, exclusive, defended winter territories in these woodlands. All observations suggest that the birds defend (or attempting to defend) an adequate supply of juniper berries to survive the winter. Salomonson & Balda (19 found that Townsend's Solitaires spent as much, if not more time wintering in pinyon-juniper woodland than on the breeding grounds. These birds should, thus, show adaptations that promote survival during the winter. Average territory size during a "bumper" berry crop averaged 0.70 ha and contained between 13 and 25 million juniper berries. Each territory contained more than a solitaire could possibly harvest. This may insure the solitaires an adequate berry supply against heavy snow, heavy consumption by flocking bluebirds and robins, and consumption by birds that sneak into their territories. At the same time the junipers make no attempt to conceal their seeds or make them difficult for animals (especially birds) to locate and consume. Thus, one must conclude that southwestern junipers rely on birds to disperse their seeds.

The other dominant trees in this woodland show the same erratic production of propagules. Pinus edulis produces large synchronized crops of seeds every 6 or 7 years and intermediate crops every three to four years (Balda 1978). Pinus monophylla produces an abundant crop of cones every two to three years (Graves 1917). References too numerous to mention (in English, Navajo and Hopi) refer to the activities of birds in the consumption of pinyon pine seeds. It is generally concluded that dispersal of the large, wingless seeds occurs by the

actions of both mammals and birds.

Estimates of how many pinyon pine seeds are carried off during good crop have been made and range from 18,000 to 33,000 seeds/autum bird (Table 12).

Table 12. Approximate number of pine seeds cached by a single bird when pinyon pine cone crop is high

Bird	Tree	Number of Seeds	Reference
Piñon Jay	Pinus edulis	21,500	Balda, 1978
Piñon Jay	Pinus edulis	18,000	Ligon, 1978
Clark's Nutcracker	Pinus edulis	22-33,000	Vander Wall and Balda, 1977

Seeds harvested from cones by the permanent resident piñon Jay a Scrub Jay are often stored in shallow subterranean caches from which they can be reclaimed at a later time (Balda and Bateman 1972, Ligon 1978). Two other corvids descend into the pinyon-juniper woodlands t harvest pinyon pine seeds. The Steller's Jay carries up to 15 seeds in its mouth and throat up into the ponderosa pine forest where they are cached. A single bird may make six or seven trips per day. If t woodlands are within 20 km of a mixed coniferous forest Clark's Nutcrackers, which often forage on and store seeds of limber pine and white-bark pine, will descend to harvest pine seeds for caching in th coniferous forest (Tomback 1977, Vander Wall and Balda 1977).

Caching sites are usually on relatively dry sites that are snow free or quick to melt. Seeds that are not found by the birds often germinate and grow. In this manner pinyon pine is planted in the woodland and in grasslands below (Ligon 1971) and in the coniferous forest above it (Vander Wall and Balda, unpubl. data). The Clark's Nutcracker, as it resembles its European congener has a remarkable memory for finding its hidden caches (Turcek and Kelso 1968, Balda in press, Tomback in press).

MANAGEMENT CONSIDERATIONS

Until quite recently the standard management procedure for pinyon-juniper woodlands was to get rid of it. This was done with little consideration for the nongame birds. Wise management guidelines of today require that we know what we are managing and the constraints imposed by each group of organisms that occur in the habitat type. Avian ecologists have long ignored this expansive plant community. The result is we do not have the data in hand to make concrete suggestions to the "What if we do..." questions so often asked by wildlife managers. We urge that a concerted, organized effort be made in the four-state region where this woodland is so abundant to find out what species are present, in what densities,

and what factors control their presence and abundance.

This woodland is biologically unique in the sense that both dominant tree species are adapted to have their seeds dispersed by animals. Here some seed predators are also mutualistic agents of the trees. This fact alone should be a constraint. Because of the mobility of the dispersal agents, type conversion projects will probably never be permanent as pinyon pine and juniper seeds will be defecated and/or cached in these "converted" areas.

The winter use of juniper berries by hundreds of thousands of robins, bluebirds and other species must also be considered. We often hear statements about the futility of trying to manage our forests and rangelands for nongame birds that winter far from the breeding grounds. The pinyon-juniper woodland is one such wintering ground and also deserves consideration from that point-of-view.

The strong correlations between various bird community characteristics and pinyon pine parameters suggest that this tree species has important implications for breeding birds. Just what these properties of pinyon pine are remains to be seen but selective removal of pinyon pine will most likely have a serious impact on the breeding bird community.

Thus, both the pinyon pine and the junipers play key roles in maintaining the integrity, survival and propagation of some (or all) components of the bird community. Both tree species provide different requisites at different times of year.

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Appendix I. -- Scientific names for bird species mentioned in the text and tables.

Common Name	Scientific Name
Turkey Vulture	*Cathartes aura*
Cooper's Hawk	*Accipiter cooperii*
Red-tailed Hawk	*Buteo jamaicensis*
Swainson's Hawk	*Buteo swainsoni*
Rough-legged Hawk	*Buteo lagopus*
Ferruginous Hawk	*Buteo regalis*
Golden Eagle	*Aquila chrysaetos*
Prairie Falcon	*Falco mexicanus*
Merlin	*Falco columbarius*
American Kestrel	*Falco sparverius*
Gambel's Quail	*Lophortyx gambelii*
Mourning Dove	*Zenaida macroura*
Screech Owl	*Otus asio*
Great Horned Owl	*Bubo virginianus*
Long-eared Owl	*Asio otus*
Saw-whet Owl	*Aegolius acadicus*
Poor-will	*Phalaenoptilus nuttallii*
Common Nighthawk	*Chordeiles minor*
Lesser Nighthawk	*Chordeiles acutipennis*
White-throated Swift	*Aeronautes saxatalis*
Black-chinned Hummingbird	*Archilochus alexandri*
Costa's Hummingbird	*Calypte costae*
Broad-tailed Hummingbird	*Selasphorus platycercus*
Common {red-shafted} Flicker	*Colaptes auratus cafer*
Hairy Woodpecker	*Picoides villosus*
Ladder-backed Woodpecker	*Picoides scalaris*
Western Kingbird	*Tyrannus verticalis*
Cassin's Kingbird	*Tyrannus vociferans*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Say's Phoebe	*Sayornis saya*
Gray Flycatcher	*Empidonax wrightii*
Western Wood Pewee	*Contopus sordidulus*
Horned Lark	*Eremophila alpestris*
Violet-green Swallow	*Tachycineta thalassina*
Cliff Swallow	*Petrochelidon pyrrhonata*
Scrub Jay	*Aphelocoma coerulescens*
Black-billed Magpie	*Pica pica*
Common Raven	*Corvus corax*
Pinon Jay	*Gymnorhinus cyanocephalus*
Clark's Nutcracker	*Nucifraga columbiana*
Mountain Chickadee	*Parus gambeli*
Plain Titmouse	*Parus inornatus*
Bridled Titmouse	*Parus wollweberi*
Common Bushtit	*Psaltriparus minimus*
White-breasted Nuthatch	*Sitta carolinensis*
Red-breasted Nuthatch	*Sitta canadensis*
House Wren	*Troglodytes aedon*
Bewick's Wren	*Thryomanes bewickii*
Cañon Wren	*Catherpes mexicanus*
Rock Wren	*Salpinctes obsoletus*
Mockingbird	*Mimus polyglottos*
Sage Thrasher	*Oreoscoptes montanus*
American Robin	*Turdus migratorius*

Appendix I. -- continued.

Common Name	Scientific Name
Western Bluebird	*Sialia mexicana*
Mountain Bluebird	*Sialia currucoides*
Townsend's Solitaire	*Myadestes townsendi*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Ruby-crowned Kinglet	*Regulus calendula*
Loggerhead Shrike	*Lanius ludovicianus*
Gray Vireo	*Vireo vicinior*
Solitary Vireo	*Vireo solitarius*
Black-throated Gray Warbler	*Dendroica nigrescens*
Scott's Oriole	*Icterus parisorum*
Brown-headed Cowbird	*Molothrus ater*
Hepatic Tanager	*Piranga flava*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Lazuli Bunting	*Passerina amoena*
Evening Grosbeak	*Hesperiphona vespertina*
Cassin's Finch	*Carpodacus cassinii*
House Finch	*Carpodacus mexicanus*
Lesser Goldfinch	*Carduelis psaltria*
Red Crossbill	*Loxia curvirostra*
Green-tailed Towhee	*Pipilo chlorurus*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Brown Towhee	*Pipilo fuscus*
Vesper Sparrow	*Pooecetes gramineus*
Lark Sparrow	*Chondestes grammacus*
Black-throated Sparrow	*Amphispiza bilineata*
Sage Sparrow	*Amphispiza belli*
Dark-eyed Junco	*Junco hyemalis*
Gray-headed Junco	*Junco caniceps*
Chipping Sparrow	*Spizella passerina*
Brewer's Sparrow	*Spizella breweri*
Black-chinned Sparrow	*Spizella atrogularis*
White-crowned Sparrow	*Zonotrichia leucophrys*

PONDEROSA PINE BIRD COMMUNITIES

Kenneth L. Diem

Professor of Zoology and Game Management
Department of Zoology and Physiology
University of Wyoming

Samuel I. Zeveloff

Department of Zoology and Physiology
University of Wyoming

ABSTRACT

Ponderosa pine forests are described with respect to the community's extensive distribution and its development under a wide range of environmental conditions. Bird species composition and distribution are discussed with respect to the vegetative structure in a community with uneven-aged aggregation of even-age tree groups. Bird species sensitive to environmental change are identified. Plight of the non-commercial forest avian resources is described. Integrated resource management of nongame birds is discussed.

KEYWORDS: nongame birds, ponderosa pine, guilds, silviculture, biogeography

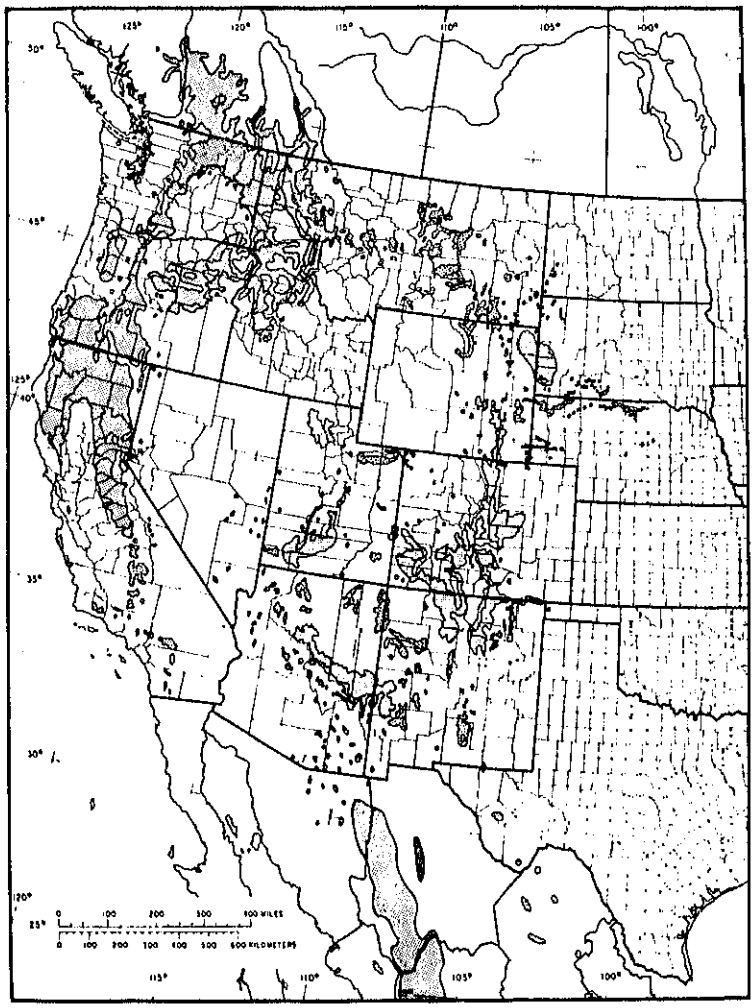


Figure 1. Range of the ponderosa pine forest in North America (Little 1971).

production for livestock and wildlife, habitat for wildlife and aesthetic landscape values. All of these conditions serve to create a very complex habitat whose complexity is amplified by the presence of two subspecies of ponderosa pine and 113 species of birds.

Frequently, the widely distributed and highly diverse uneven-aged nature of the ponderosa pine habitat conflicts with man's single use objectives of piecemeal resource management. Also, too often, limited knowledge and poor inter-profession communication are integral parts of single objective resource management and lead to unanticipated and undesirable results (Bandy and Taber 1974). Timber management can

be designed to protect the forest environment but many times it is incompatible with the management objectives of one or more non-timber resources.

It is not the purpose of our paper to duplicate materials well covered in the proceedings of other nongame workshops or in the recent excellent studies of Szaro and Balda (1979a) and Thomas (1979). Rather, the objectives of this presentation are to: 1) provide an overview of the unique character of the ponderosa pine community; and 2) identify the other types of information which would serve to facilitate the institution of better nongame bird management coincident with truly integrated forest resource management.

PONDEROSA PINE HABITAT

Tree Characteristics

Interior ponderosa pine trees grow to be 53 m tall and 128 cm in diameter. In the Rocky Mountain region, heights of 18 to 38 m and diameters of 50-75 cm are more typical for an old mature tree. They are generally strongly rooted and, depending on the substrate, roots may penetrate to depths of 10-12 m. Lateral root development varies according to tree density and is closely related to crown width except in more open stands where roots may extend up to 30 m (Schubert 1974). Such root development can severely influence and regulate the availability of soil moisture for understory vegetation. Tree growth is relatively slow and stands of young trees or blackjacks (black bark with ages of 120-150 yrs.) can be separated from yellowbellies or mature, over-mature and old trees (dark cinnamon to yellow bark, aged 120 to >200 yrs.).

Depending on site conditions, seed production generally begins with mature trees that are 30-40 cm d.b.h. (120-150 years old). Prime seed producers appear to be in the 60-72 cm d.b.h. class with good to excellent seed crops occurring at 2-5 year intervals (Larson and Schubert 1970, Boldt and VanDeusen 1974). Geographic variations modify this; southwest ponderosa pine maturesat an earlier age and have smaller diameters than in the northern and western ranges (Thomson 1940). Exposed mineral soil seed beds, resulting from fires or mechanical disturbances, are essential for seedling establishment. Natural seeds commonly produce high density seedling stands, particularly where (1) fires have produced timely exposure of the mineral soil and additional soil nutrients, and have reduced competitors for soil moisture; and (2) where either snow cover or overhead canopy cover protects the seedlings from frost and frost heaving. Also, a high tree density is maintained because natural thinning is such a slow process and frequently results in stands of 37,000 12 year-old trees/ha declining to 16,000 63 year-old trees/ha having an average d.b.h. of 6.4 cm (Boldt and VanDeusen 1974, Schubert 1974).

Where trees grow with wide stand spacing, they tend to develop large crowns which occupy a relatively large proportion of the entire length of the stem. The trunks of such trees have a relatively short cylindrical stem below the live crown and a long tapered section within the crown. Conversely, naturally pruned, closely growing trees, will have the opposite characteristics (Larson 1963, 1964).

General Forest Environment

It is obvious from the above that interior ponderosa pine forests have developed under widely ranging environmental conditions. This species may grow at elevations

between 1800 m and 3000 m, where annual precipitation averages 26-62 cm and seasonal temperature extremes range from 98 F to -40 F. In general, the climatic environment could be classified as arid to subhumid and cool to warm. With increasing elevations temperature becomes more important than moisture as a limiting factor (Boldt and VanDeusen 1974, Schubert 1974, Gary 1975).

As with climatic variations, ponderosa pine forests are found on a variety of substrates. Generally, igneous and sedimentary substrates are more productive than soils of metamorphic origin. Loamy limestone soils with moderate to low concentrations of calcite and a diversity of chemical components are among the most productive soils, i.e., the Kaibab limestone soils which produce as much as 86,000 fbm/ha. Weathered, deep, granitic and basalt soils are also quite productive. Sandstone soils can be productive, particularly if calcium carbonate and feldspars are present. Usually, the low productive soils are: 1) the shallow, poorly weathered, droughty igneous soils; 2) the shallow, limestone soils which are high in calcite; 3) coarse sandstone soils that have a high silica content; 4) deep shale soil ; and 5) soils derived from metamorphic schists, gneisses and quartzites (Schubert 1974).

Forest Composition and Distribution

In the cooler, more moist areas the formation of forests dominated by yellow pine with one exception, the Black Hills forest, generally represent aggregations of all-aged forests made up of conspicuous even-aged groups. This patchy pattern of trees appears to be the result of ponderosa pine intolerance to shade and the relatively small forest openings available for seedling establishment. Natural fires have amplified the character of this grouping and served to maintain it over time (Cooper 1960). By contrast, the Black Hills yellow pine forests are considered to be primarily an even-aged forest (Boldt and VanDeusen 1974); a trait that is probably the result of very intensive historic timber utilization and/or the influence of widespread fire.

The successful suppression of fire eliminated selective removal of small yellow pine seedling stems and intensive grazing by domestic livestock removed grass and herbaceous cover competitors for those seedlings. Consequently, current forests are characterized by increased areas and densities of ponderosa pine reproduction stands (Cooper 1960, Schubert 1974). Although increased tree densities can limit grazing, they also severely reduce the herbaceous ground cover. Jameson (1967) found that southwestern yellow pine forest clearings produced 674 kg of herbage per acre while tree stands having a basal area of 23 m^2/ha (100 ft^2/acre) produced only 56 kg. Even where park-like openings occur in yellow pine forests, increased grazing pressure can cause a shift from mid-grasses (fescue, muhly, Junegrass) to shortgrasses (blue grama and squirreltail) (Cooper 1960).

Throughout the lower elevations with warmer, more arid foothill sites, savannahs with well developed grasslands and open-growing ponderosa pines are found. However, in the southern regions, these savannah-like areas are conspicuous by their absence. Lower moisture levels, increased competition from grasses for limited moisture, phytotoxicity of grasses to yellow pine seedlings, and heavy grazing pressures have served to maintain the openness of these savannah stands (Schubert 1974). Between the two extremes of strongly dominant ponderosa pine stands and the ponderosa pine savannahs, a wide range of transitional forest types are formed involving shrubs, deciduous trees and other conifers. Brief descriptions of four forest areas representative of the ponderosa pine community are presented below.

Pure Pine: Uneven-aged Stand and Even-age Groups of P.p. scopulorum

Gross descriptions of representative yellow pine forests have traditionally used the nearly pure ponderosa forest, with its parklike understory, extending 480 km across the Kaibab and Mogollon areas of northern and central Arizona (Fig. 2). Generally, this forest type has fewer trees of other species. The understory includes numerous shrubs and extensive parklike stands of grass.

Pure Pine: Even-aged Stand of P.p. scopulorum

The Black Hills forest is nearly a pure stand of even-aged yellow pine, with few trees of other species, extending for roughly 160 km from western South Dakota to northeastern Wyoming (Fig. 2). Very limited stands of white spruce, lodgepole pine and limber pine can be found. Rocky Mountain juniper is sparsely associated with the yellow pine along the foothills areas. The most abundant deciduous tree is the quaking aspen, generally found on old forest fire burns on limestone and igneous soils. Along the foothills, typically in bottomlands, one finds bur oak trees and shrubs. The paper birch occurs rarely on limited moist sites. In contrast to the relatively few overstory species, the understory vegetation is quite diverse. Finally, the substrate for this forest is largely limestone with a mixture of sandstone and shale and a central crystalline area of schist with some granite (Boldt and VanDeusen 1974).

Mixed Species: Uneven-aged Stand of P.p. scopulorum

In contrast with the nearly pure stands of important commercial timber, a forest of sparse, open growing yellow pine extends from southern Wyoming in a narrow belt for approximately 240 km along the Colorado Front Range (Gary 1975). The soils of this forest type are primarily granitic (90%), tend to be droughty, have low productivity and erode easily. In addition to the natural environmental constraints of the abruptly rising Front Range, historic influences of logging, grazing, mining, as well as, current heavy urban developments continue to manifest themselves on this plant community.

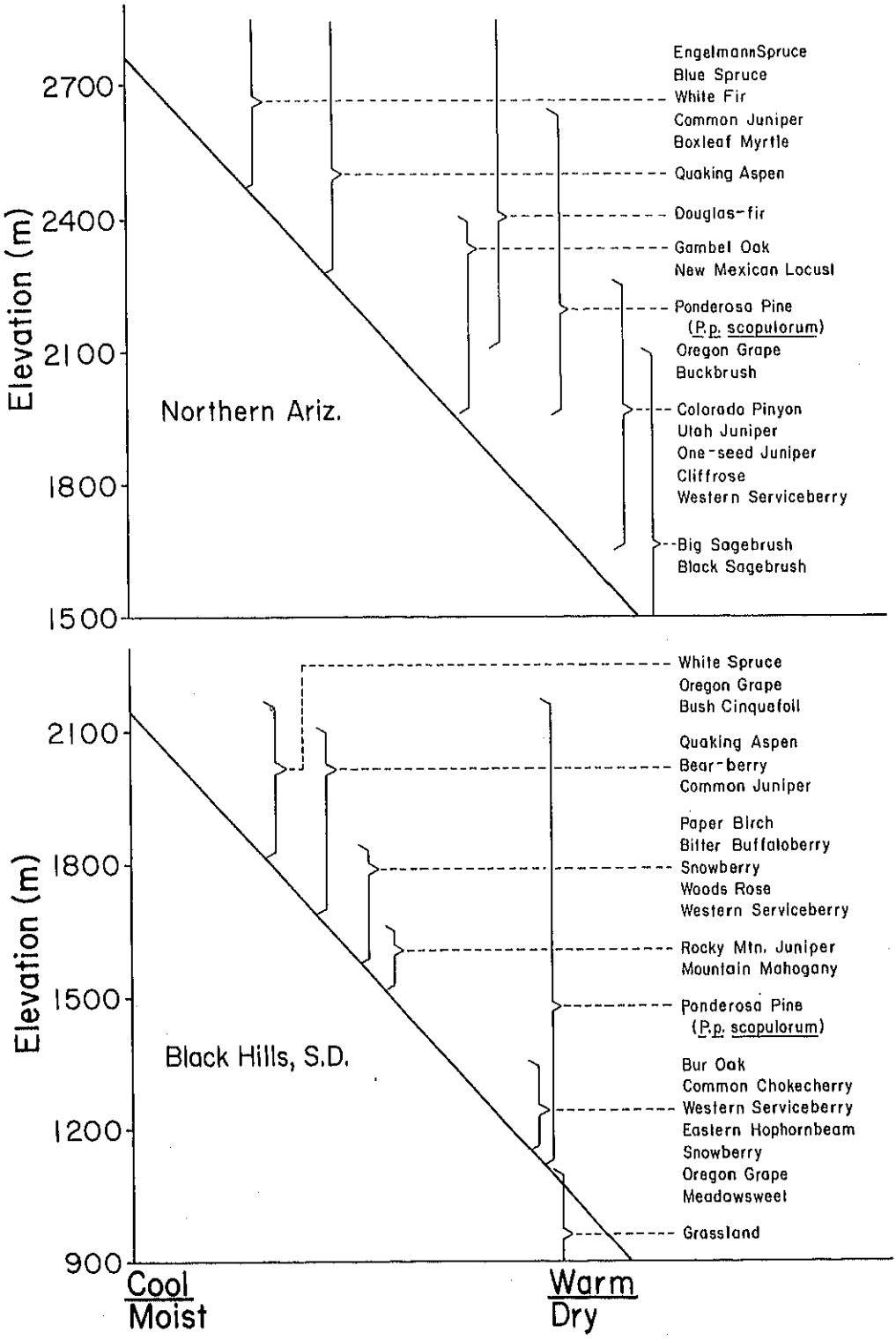
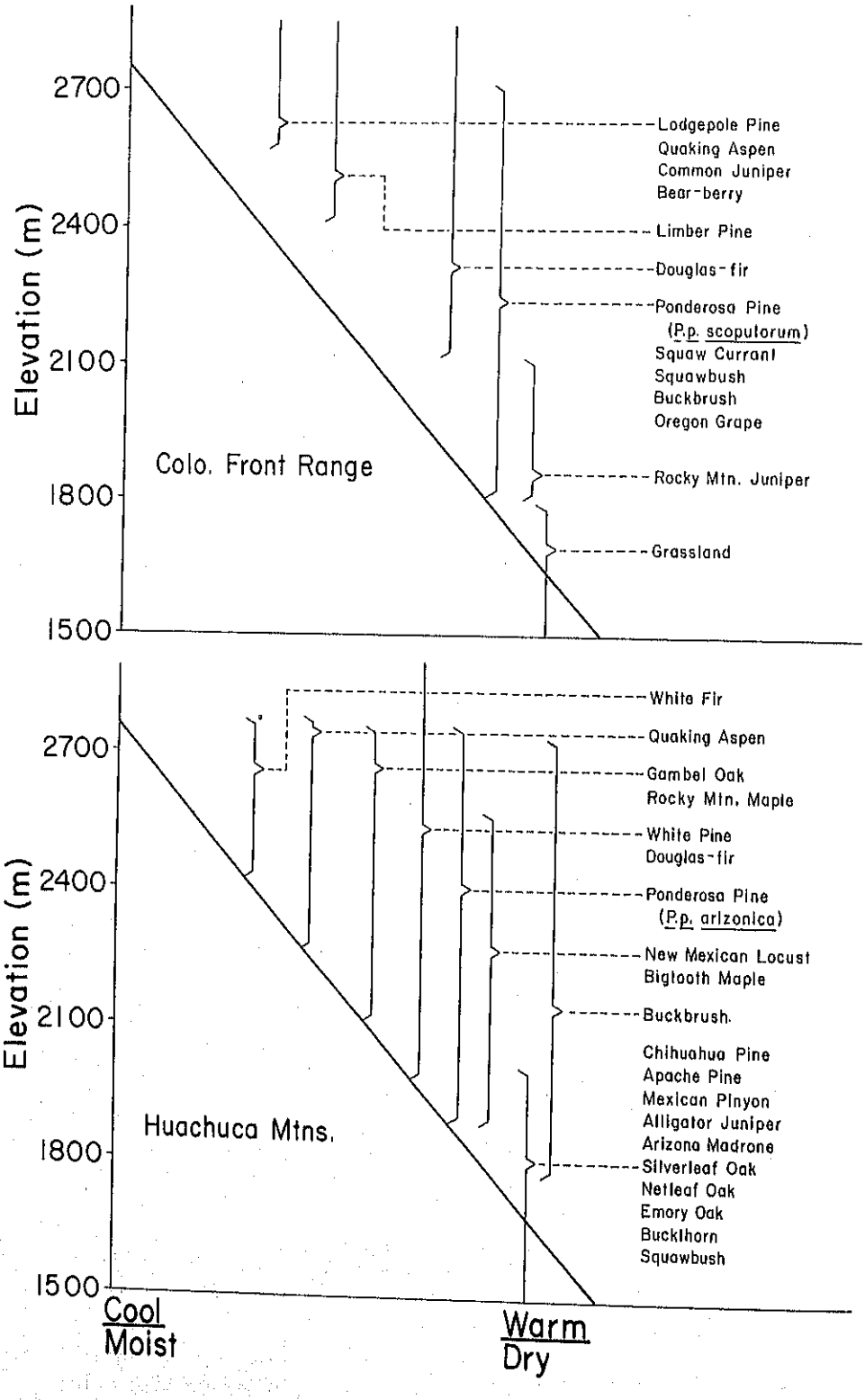


Figure 2. Vegetative components of the ponderosa pine community's four representativ locations; northern Arizona; Black Hills, South Dakota; Colorado Front Range; and Huachuca Mountains, Arizona (Lowe 1964, Thilenius 1972, Marrs 1967, and Wallmo 1955).



re 2. (Continued)

The two most prominent shrubs throughout this forest type are buckbrush and New Mexican locust; the former frequently forming thickets where the forest becomes more open and the latter being a large shrub or small tree.

AVIAN COMPONENTS

Approximately 113 species of birds representing 49 nesting and feeding guilds reside in the yellow pine forests (Table 1). This diversity is a direct reflection of the community's highly complex character and this diversity may demonstrate the potential of the avian community to respond to change. Unfortunately, this very same diversity can obscure serious declines of low density avian species. Table 2 summarizes the status of those avian species which are known or thought to have declining populations. Even though the total of endangered and threatened species is relatively low, a suggested declining state for 22% of the bird species is a matter for serious concern. The situation appears to be particularly serious for the Barn Owl, Lewis' Woodpecker, White-breasted Nuthatch and the Western Bluebird because the restriction of these species to 2 or 3 plant communities and 2 or 3 seral stages naturally limits their ability to respond to environmental change. Importantly, they are further constrained by their dependence on tree cavities for reproduction.

Detecting significant environmental changes requires the monitoring of particularly sensitive species of birds. Thomas et al. (1979a) describes a versatility index for wildlife species which includes some of the limitation criteria listed in Table 2. The low versatility of a bird species reflects its potential sensitivity to environmental change; a reaction that is amplified if the species were a year-long resident in the forest. Unfortunately, few data have been gathered on year-long resident birds in the ponderosa pine forests; Rasmussen (1941) and Balda (1967, 1975) have identified 23 year-long species. From their data we have compiled a list (Table 3) of bird species which could be monitored as particularly sensitive environmental indicators in the various associations of the ponderosa pine community.

Unfortunately, enthusiasm for acquiring avian diversity data, has all too often resulted in overemphasizing the concept that "more is better". There has been an inclination by the manager to equate species richness with either large numbers of species and few individuals or fewer species with larger numbers of individuals. Rather than producing numbers, we must begin to manage birds with respect to their natural role and function in the ecosystem. For those larger species of raptors, i.e., goshawks or eagles, the optimum environment may never be able to support populations except at low individual densities and low species levels. Rasmussen (1941) estimated that the density of goshawks in 1931 in the North Kaibab ponderosa pine was 1 goshawk per 13 km^2. Shuster (1977) found that in Colorado they nested at a minimum density of 1 pair per 13.3 km^2. Reynolds (1978) calculated that for the Cooper's Hawk in Oregon, densities ranged from 1 nest per 5.1 km^2 to 1 nest per 7.2 km^2.

This overemphasis on species diversity has overlooked the vital importance of the old growth habitat with detrimental results for the species narrowly restricted to it (Bandy and Taber 1974, Wight 1974, Verner 1975, Edgerton and Thomas 1977). Furthermore, subtle species habitat requirements can be easily overlooked. The optimum Northern spotted owl habitat appears to include not only dense growth ponderosa pine stands of 243 ha or more, but heavily shaded, cool stands mixed with Douglas-fir with water sources close by (Zarn 1974).

Table 1. Nesting and feeding guild classification of ponderosa pine forest birds (Rasmussen 1941, Balda 1967, Behle and Perry 1975, Thomas 1979a).

Guild	Species
CONIFER TREE NESTER	
Foliage Gleaning Insectivore	Golden-crowned Kinglet
	Ruby-crowned Kinglet
	Olive Warbler
	Yellow-rumped Warbler
	Black-throated Gray Warbler
	Townsend's Warbler
Foliage Gleaning Granivore	Western Tanager
Foliage Gleaning Omnivore	Red Crossbill
	Gray Jay
	Pinyon Jay
	Clark's Nutcracker
Ground Gleaning Granivore	Band-tailed Pigeon
Aerial Sally Feeding Insectivore	Olive-sided Flycatcher
CONIFER-DECIDUOUS NESTER	
Foliage Gleaning Insectivore	Solitary Vireo
	Red-eyed Vireo
	Warbling Vireo
	Grace's Warbler
	Hepatic Tanager
Foliage Gleaning Granivore	Black-headed Grosbeak
	Evening Grosbeak
	Pine Grosbeak
Foliage Gleaning Omnivore	Pine Siskin
	Steller's Jay
	House Finch
	Purple Finch
Foliage Nectivore-Insectivore	Rivoli's Hummingbird
Ground Gleaning Insectivore	
Ground (Riparian) Gleaning Insectivore	American Robin
Ground Gleaning Granivore	Solitary Sandpiper
	Cassin's Finch
Ground Feeding Omnivore	Mourning Dove
	Common Raven
Ground Feeding Carnivore	Common Crow
	Goshawk
	Sharp-shinned Hawk
	Cooper's Hawk
	Red-tailed Hawk
	Golden Eagle
	Bald Eagle
	Merlin

Table 1 (Continued).

Guild	Species
Aerial Sally Feeding Insectivore	Hammond's Flycatcher
	Western Flycatcher
	Coues' Flycatcher
	Western Wood Pewee
Water Feeding Piscivore	Osprey
DECIDUOUS TREE NESTER	
Foliage Gleaning Insectivore	Northern Oriole
BUSH AND SMALL TREE NESTER	
Foliage Gleaning Insectivore	Bushtit
Foliage Gleaning Granivore	American Goldfinch
Foliage Nectivore-Insectivore	Broad-tailed Hummingbird
	Calliope Hummingbird
	Blue-throated Hummingbird
Ground Gleaning Insectivore	American Robin
Ground (Riparian) Gleaning Insectivore	Solitary Sandpiper
Ground Gleaning Granivore	Chipping Sparrow
Ground Gleaning Omnivore	Black-billed Magpie
	Brewer's Blackbird
	Brown-headed Cowbird
	Green-tailed Towhee
Ground Feeding Carnivore	Loggerhead Shrike
Aerial Sally Feeding Insectivore	Gray Flycatcher
	Dusky Flycatcher
GROUND NESTER	
Foliage Gleaning Insectivore	Red-faced Warbler
Foliage Feeding Omnivore	Blue Grouse
	Ruffed Grouse
	Hermit Thrush
	Townsend's Solitaire
Ground Gleaning Insectivore	Virg
Ground Gleaning Granivore	Da[illegible]
	Gr
	Me
Ground Gleaning Omnivore	Mo
	Tu
Aerial Feeding Insectivore	Wh
	Po
	Co
GROUND RIPARIAN NESTER	
Water Gleaning Insectivore	Di
CLIFF, CAVE, ROCK OR TALUS NESTER	
Ground Gleaning Insectivore	Ca
	Ro

Table 1 (Continued).

Guild	Species
Ground Feeding Carnivore	Turkey Vulture
	Ferruginous Hawk
Ground Gleaning Omnivore	Common Raven
Aerial Sally Feeding Insectivore	Say's Phoebe
	Western Flycatcher
Aerial Feeding Insectivore	Black Swift
	White-throated Swift
Aerial Feeding Carnivore	Prairie Falcon
	Peregrine Falcon
CONIFER-DECIDUOUS CAVITY NESTER, EXCAVATION BY OTHER WILDLIFE OR IN A NATURAL CAVITY	
Foliage Gleaning Insectivore	House Wren
Timber Gleaning Insectivore	Black-capped Chickadee
	Mexican Chickadee
	Mountain Chickadee
	Brown Creeper
Ground Gleaning Insectivore	Western Bluebird
	Mountain Bluebird
Ground Feeding Carnivore	American Kestrel
	Barn Owl
	Flammulated Owl
	Pygmy Owl
	Barred Owl
	(Mexican) Spotted Owl
	Saw-whet Owl
Aerial Sally Feeding Insectivore	Ash-throated Flycatcher
Aerial Feeding Insectivore	Violet-green Swallow
	Tree Swallow
CONIFER-DECIDUOUS CAVITY NESTER, THEIR OWN CAVITY EXCAVATION	
Timber Gleaning Omnivore	White-breasted Nuthatch
Timber Drilling Insectivore	Pygmy Nuthatch
	Pileated Woodpecker
	Hairy Woodpecker
Timber Drilling Omnivore	White-headed Woodpecker
	Northern Three-toed Woodpecker
	Acorn Woodpecker
	Lewis' Woodpecker
	Yellow-bellied Sapsucker
Ground Gleaning Insectivore	Williamson's Sapsucker
	Common Flicker

Table 2. Status, limitations and special requirements of bird species with known declining populations or with indicators of a declining population (Arbib 1979, Thomas 1979).

Species	Status		Limitations				Special Requirements	
	Endangered and Threatened	Amer. Bird Blue List	2-3 Plant Communities Repr.	2-3 Plant Communities Feeding	2-3 Successional Communities Repr.	2-3 Successional Communities Feeding	Tree Cavity Nester	Mature and Old Timber Growth
Turkey Vulture		x			x	x		
Sharp-shinned Hawk		x	x		x			
Cooper's Hawk		x			x			
Ferruginous Hawk		x			x	x		
Bald Eagle	x		x		x			x
Osprey		x	x		x			x
Prairie Falcon		x	x		x	x		
Peregrine Falcon	x							
American Kestrel		x			x	x		
Merlin		x			x			
Band-tailed Pigeon		x	x					
Barn Owl		x			x		x	x
Long-eared Owl		x			x			
Whip-poor-will		x						
Common Nighthawk		x						
Lewis' Woodpecker		x	x	x	x		x	
Hairy Woodpecker		x			x	x	x	
White-breasted Nuthatch		x	x	x	x	x	x	x
Western Bluebird		x	x		x	x	x	
Mountain Bluebird		x			x	x	x	
Golden-crowned Kinglet		x			x			
Ruby-crowned Kinglet		x			x			
Loggerhead Shrike		x	x					
Warbling Vireo		x	x					

Table 3. Selected bird species capable of serving as sensitive environmental indicators in the ponderosa pine forest community.

Species
Goshawk
Barn Owl
Common Flicker
Lewis' Woodpecker
Hairy Woodpecker
White-breasted Nuthatch
Pygmy Nuthatch
Western Bluebird
Mexican Junco
Gray-headed Junco

MANAGEMENT CONSIDERATIONS

Community Associations

Throughout its range, the unique diversity of the ponderosa pine community is its most characteristic and valuable asset (Rasmussen 1941, Cooper 1960, Lowe 1964, Balda 1967, Marrs 1967, Thilenius 1972, Schubert 1974, Pfister et al. 1977, Thomas 1979). Consequently, successful management of the ponderosa pine forest habitat for nongame birds, as well as all forest resources, must provide for natural diversity. Basic to such management is the identification and characterization of the habitat associations of the ponderosa pine community. As used here, the association hierarchy consists of the forest (coniferous) subdivided according to the dominant tree species (ponderosa pine) which are then broken down into one or more associations, i.e., ponderosa pine/common snowberry/bear-berry. Some of these associations have been identified for local areas (Table 4). The land type classification presented by Hall and Thomas (1979) greatly enhances the value of association classification. In the interest of standardization, the need is greatest to identify and describe the vast number of ponderosa pine associations which remain unclassified. By itself plant species composition is not so important but insofar as it characterizes the vegetative structure and volume of a particular vegetative stratification or subdivision it is valuable to birds (Szaro and Balda 1979a).

Information Categories

Environmental conditions and people pressure on the forest resources require a much greater intensity of integrated resource management than in the past. Not only does this demand the collection of a greater array of information about forest ecosystem resources but there is also the need for intensive interaction between a broad spectrum of resource managers; i.e., forest, range, wildlife, water, mineral, soil, recreation, etc. This will be facilitated by data standardization which promotes information compatability and comparability. Table 5 contains a summary of standard

Table 4. Association classification of the ponderosa pine community in the South Dakota Black Hills, Montana and Oregon.

Black Hills (Thilenius 1972)	Montana (Pfister et al. 1977)	Oregon (Hall 1973)
P. p./common juniper/common snowberry/Oregon grape	P.p./common chokecherry	P.p./Douglas-fir/snowberry-oceanspray
P.p./bitter buffaloberry/common snowberry/bear-berry	P.p./common snowberry	P.p./Douglas-fir/elk sedge
P.p./shrubby potentilla/common snowberry/woodland strawberry	P.p./bitterbrush	P.p./Douglas-fir/ninebark
P.p./Mtn. snowberry/woods rose/Kentucky bluegrass	P.p./Idaho fescue	P.p./bitterbrush/Ross sedge
P.p./common snowberry/bear-berry	P.p./bluebunch wheatgrass	P.p./fescue
P.p./bur oak/common chokecherry/common snowberry/Oregon grape	P.p./bluestem	P.p./wheatgrass
P.p./bur oak/common chokecherry/common snowberry/false melic-sedge		P.p./blue wildrye
P.p./common chokecherry/western serviceberry/twinleaf bedstraw		
P.p./Kentucky bluegrass/timber oatgrass		
P.p./common juniper/mountain mahogany		
P.p./little bluestem		
P.p./common juniper/little bluestem		
P.p./little bluestem-blue grama		

information vital to management of nongame birds and other resources common to the ponderosa pine community.

Selection and use of common forest resource inventory and monitoring sites has not been widespread. However, such sites are necessary for permanent baseline data reference. Mapping plots used by foresters for many years have been adopted by the European Avian Atlas Committee and the International Bird Census Committee (Svenson 1970). In Wyoming, common mapping plots are being used for the integrated collection

Table 5. Categories of basic information universally applicable to nongame bird management and integrated resource management in the ponderosa pine community.

Information Category	Specific Information to be Acquired	Reference
Living Tree Classification		
Age and succession	d.b.h. size	Schubert 1974
Vigor	Tree height, crown height, crown volume	Schubert 1974
Potential soft snag	Evidence of heart rot	
Tree position	Trees isolated	Thomas et al. 1979b
	Open grown, but near group	
	Marginal grown, edge of group	
	Interior grown, inside group	
Tree dominance	Dominant-crown above general crown level	Larson and Schubert 1970
	Codominant-crown forming general crown level	
	Intermediate-shorter trees but crowns extend into general crown level	
	Suppressed-trees with crowns entirely below crown level	
Snag Classification		
Size and condition	d.b.h. and height, hard or soft snags	Thomas et al. 1979b
Actual or potential cavities	Number of natural, excavated or loose bark cavities	
Successional stages	Nine decomposition stages	
Forest Stand Classification		
Tree stocking density	Basal area/ha (acre)	Schubert 1974
	Number of stems/ha (acre)	Ford-Robertson 1971
Tree damaging agent	% crown cover	Szaro and Balda 1979a
	Causal damage agent: light, moderate, or heavy degree of severity	Schubert 1974
Seed trees (24-36 d.b.h. crown 35-70% of tree height, fair to good vigor)		
Understory vegetation	Basal area/ha (acre)	Larson and Schubert 1970
	Height, % crown cover foliage volume, forage and browse production	Schubert 1974
Down Log Classification	Diameter and length, number of logs/ha, distribution pattern, degree and type of decay, decomposition class	Maser et al. 1979

Table 5 (Continued).

Information Category	Specific Information to be Acquired	Reference
Fuel Classification	Litter depth	Deeming et al. 1978
Edge Classification (inherent and induced)	Length, width of ecotone, abrupt or mosaic configuration, degree of vegetational structure contract and habitat size	Thomas et al. 1979c
Avian Species Classification Nesting, roosting and feeding guilds	Specific activity by species, duration in time, time of day and season, location of activity by tree species, minimum nesting height, minimum d.b.h. for nesting and size of territory	Salt 1957, Root 1967, Willson 1974, Szaro and Balda 1979a

of ecosystem data on wildlife species and their habitats. Using the optimum size of the plots suggested by the International Bird Census Committee (Svenson 1970), Wyoming's mapping plot sizes are 42 ha for open canopy habitat and 12 ha in closed habitat (Diem 1976). No other single avian census method has the versatility for sampling, recording, relocating and comparing of avian population and habitat data to say nothing about how mapping plots serve as adequate integrated data collection sites for other resources. The location and number of these mapping plots depend on the number of habitat associations in the ponderosa pine community, as well as, special management considerations; i.e., stand condition, contemplated management practices, etc., (see below).

Commercial Timber

Silvicultural Practices

Wight (1974), Buttery and Shields (1975), Bull (1977), Edgerton and Thomas (1977), Kindschy (1977), Hall and Thomas (1979), Szaro and Balda (1979a and 1979b), have thoroughly discussed a variety of management practices applicable to nongame birds in the ponderosa pine community. The need for selection of the most appropriate management practice frequently outdistances the availability of adequate and certainly optimum baseline data. In the case of long lived ponderosa pine, deferring an integrated ponderosa pine management decision too long may mean the loss of a specific portion of that habitat for as much as 200-300 years! Therefore, in some cases implementation of certain forest management practices can be justified if they serve the needs of integrated forest values.

Under optimum growing conditions the uneven-aged traits and resistance to fire produce few large natural openings in the ponderosa pine forests. In the evaluation

more difficult as time passes. Scott et al. (1978) emphasized that living trees, normally considered culls because of their broken tops, lightning scars, and mistletoe infested crowns are utilized by cavity nesters. Such trees would not be attractive for firewood. Furthermore, increased longevity of a living tree would facilitate their serving as a replacement for the less durable dead snags. In the absence of culls, selected living trees could be developed as potential snags by mechanically treating all or part of the crown, i.e., girdle the tree in such a fashion that varying portions of the crown simulate a lightning struck tree.

Because of the uneven-aged stand character of most ponderosa pine communities, the distribution of the snags may be more important than previously recognized. Snag distribution should logically mimic pristine unmanaged conditions. In this regard, a variety of smaller diameter snags may be better clustered in different sized groups as they might occur in a normal even-aged group of yellow pine. Snag distribution in such groups should have interior, as well as marginal trees. One or more larger, actual or potential snag trees may also be included depending on the size of the group. These isolated larger snags or potential snag trees should be preferably >33 cm d.b.h. (Cunningham et al. 1980). Seed trees can be excellent potential snag trees if left undistrubed. This modification from a more-or-less random distribution could provide better cavity roosting cover, particularly in the winter, as well as more concentrated feeding substrates. This patterned distribution of potential snags may also provide feeding perches with better protective cover and a greater potential concentration of prey items than are available at a wide open, exposed single snag habitat. Furthermore, snags left within a group of trees are less visible to the human eye as a potential source of firewood. The suggested combination of irregular shelterwood-thinning silviculture practices could be integrated with the location and protection of potential and existing snags.

Over the wide range of the ponderosa pine forest, development and persistence of snags will be highly variable. It does appear from Cunningham et al. (1980) and Thomas et al. (1979b) that about 5-6 snags/ha of mixed size classes ranging from 10-15 cm d.b.h. to a majority composed of >25 cm d.b.h. would be adequate. Because of their smaller volume, smaller diameter snags have a shorter longevity and may be more difficult to transform from hard to soft snags for attractive excavation sites.

There appears to be a real need to assess the distribution and classification of snags in unlogged forests not subject to firewood collection. Although too few ponderosa pine forests are in wilderness areas, isolated tracts provide the opportunity for productive research on both snags and down wood.

Non-Commercial Timber

Except for Balda's (1967) work, interior ponderosa pine community bird studies have generally emphasized commercial timber habitat. Roughly 1/3 of the ponderosa pine forest habitat consists of open forest and savannah woodland having a stocking rate of 40% or less and crown cover that is 60% or less (Penfound 1967, Schubert 1974). These open non-commercial timber lands are critical habitat for 50% or more of the sensitive bird species in Table 2. Such stands occur at lower elevations, hence, they are closer to the impact of human population growth, and its attendant development. Also, being more open, the habitat is more easily penetrated by human activities of all types. Thus, grazing, vegetation manipulation, recreational activities (shooting, rock climbing, off-road vehicle travel, camping, etc.) and low flying aircraft have been able to encroach on and modify large segments of this important bird habitat. There is a critical lack of baseline data to accurately measure the degree of this encroachment, as well as the extent of the changes

that it has brought about.

Probably the most critical modification and/or loss of ponderosa pine habitat is occurring in these open forest stands because it is essentially unregulated. The accelerated rate of this change and/or loss of habitat is facilitated by the checkerboard pattern of private land and public lands and the myriad of regulatory authorities which complicate and more often inhibit attempts to implement integrated management. These conditions are sufficient justification for initiating a crash program to develop baseline information before the habitat and faunal resources are irreparably modified or destroyed. Despite the lack of baseline data, implementation of some integrated management practices is still possible. Call (1979) discusses a variety of management practices for raptorial birds and their habitat and many are readily adapted to other bird species.

Special attention should be given to the many non-commercial stands which occur as islands of ponderosa pine habitat. The southern Arizona mountains are good examples of forested "islands" in a "sea" of desert (Brown 1971) (Fig. 1). Many of these "islands" have played important biogeographic roles (MacArthur and Wilson 1967) in the distribution and survival of birds. Balda (1967) points out that the isolated ponderosa pine habitat of the southern Arizona mountains supports good breeding populations of two Mexican bird species, the Mexican Junco and the Mexican Chickadee. At the same time, a number of Rocky Mountain species (Williamson's Sapsucker and Townsend's Solitaire) normally breeding in the ponderosa pine community have been excluded from breeding in the same "island" habitats, although they winter there. The habitat and environmental conditions regulating these and other "island" species populations may provide important information for management of the ponderosa pine community as a whole (Diamond 1975, Nudds 1979). Time is rapidly running out for many of these isolated habitats since they are more vulnerable to decimating environmental pressures than are the larger segments of ponderosa habitat. A high priority must be given to the collection and analysis of baseline data from these island habitats to facilitate identification and protection of critically important areas.

Integrated Planning

Uses of the various forest resources, i.e., timber, forage, water, wildlife and aesthetic values, are usually competitive. To integrate management of these uses, there is a continuing need to acquire "fine tuning" methodology to assist in increasing the scientific aspects and hence soundness of resource decision making. Clary et al. (1975) determined the optimum level of beef and timber production based on commodity prices and productivity of the ponderosa pine habitat. Using 1972 prices, beef and timber production were optimized when the basal area of ponderosa pine trees ranged between 4 - 6 ca (45-65 ft^2). Development of a similar approach for the broader range of forest resources is possible and should be pursued. With respect to nongame birds, the environmental evaluation system developed by Graber and Graber (1976) could provide important inputs to the foregoing approach or to some other method. Their system is particularly important in that it relates the management decision to (1) replacement cost of the habitat as measured in time; (2) the availability of the habitat in relation to the total area in a geographic unit; (3) the increasing, decreasing or stable availability of a habitat; (4) the extent of the habitat in the impact area; and (5) the biotic complexity of the habitat.

CONCLUSIONS AND RECOMMENDATIONS

The great strengths of the ponderosa pine community are its adaptability to the wide variety of environmental conditions naturally represented throughout its range and the uneven-aged 3-dimensional patchiness which fosters extensive differential space exploitation. It is imperative that every effort be made to avoid any reduction or impairment of that diversity which would result in a loss of bird species and/or the numbers inhibiting that community. We also reemphasize that monitoring of avian population changes should be long term processes. Neither can we overlook the admonition of Fretwell (1972) and Willson (1974) that many critical events may take place during the non-breeding season. Consequently, the breeding densities of birds all too often reflect the numbers of birds surviving the winter rather than attributes or detriments of the breeding habitat. This further serves to emphasize the importance of monitoring the year-long resident species. Even then, one must recognize how the motility of the birds may reflect local perturbations which may be temporary responses to short term environmental factors, i.e., food source failures.

Specific recommendations are:

1. Habitat or association typing of the ponderosa pine community should be accelerated with cooperative State and Federal efforts being made to characterize the size and location of those types.

2. Permanent mapping plots should be systematically established and utilized for common collections of integrated baseline resource data. More importantly, such plots should serve to monitor long-term avifauna changes resulting from different management practices.

3. Critical or sensitive avian species selected for monitoring should include both seasonal and year-long resident species identified as either declining or probably declining.

4. The nongame bird resources of the open forest and savannah associations of the ponderosa pine community should receive immediate and overdue management attention. Collection of baseline data from these associations should receive a very high priority.

5. A combination of thinning and shelterwood cutting should be evaluated as a means of maintaining a continuum of mature and old growth stands of 140 and 240 years-of-age, respectively.

6. New options for creating and protecting snag trees should be developed and evaluated; particularly, the use of live snag trees and designed distribution patterns for snags or potential snags.

ACKNOWLEDGMENTS

This paper is dedicated to D. I. Rasmussen and Gilbert Schubert who set the standards for research in the ponderosa pine community.

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Appendix I. Nomenclature of birds and plants mentioned in the text.

Birds

Turkey Vulture	*Cathartes aura*
Goshawk	*Accipiter gentilis*
Sharp-shinned Hawk	*Accipter striatus*
Cooper's Hawk	*Accipiter cooperii*
Red-tailed Hawk	*Buteo jamaicensis*
Ferruginous Hawk	*Buteo regalis*
Golden Eagle	*Aquila chrysaetos*
Bald Eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
Prairie Falcon	*Falco mexicanus*
Peregrine Falcon	*Falco peregrinus*
Merlin	*Falco columbarius*
American Kestrel	*Falco sparverius*
Blue Grouse	*Dendragapus obscurus*
Ruffed Grouse	*Bonasa umbellus*
Mountain Quail	*Oreortyx pictus*
Turkey	*Meleagris gallopavo*
Solitary Sandpiper	*Tringa solitaria*
Band-tailed Pigeon	*Columba fasciata*
Mourning Dove	*Zenaida macroura*
Barn Owl	*Tyto alba*
Flammulated Owl	*Otus flammeolus*
Great Horned Owl	*Bubo virginianus*
Pygmy Owl	*Glaucidium gnoma*
Barred Owl	*Strix varia*
Mexican Spotted Owl	*Strix occidentalis lucida*
Long-eared Owl	*Strix nebulosa*
Saw-whet Owl	*Aegolius acadicus*
Whip-poor-will	*Caprimulgus vociferus*
Poor-will	*Phalaenoptilus nuttalii*
Common Nighthawk	*Chordeiles minor*
Black Swift	*Cypseloides niger*
White-throated Swift	*Aeronautes saxatalis*
Broad-tailed Hummingbird	*Selasphorus platycercus*
Calliope Hummingbird	*Stellula calliope*
Rivoli's Hummingbird	*Eugenes fulgens*
Blue-throated Hummingbird	*Lampornis clemenciae*
Common Flicker	*Colaptes auratus*
Piliated Woodpecker	*Dryocopus pileatus*
Acorn Woodpecker	*Melanerpes formicivorus*
Lewis' Woodpecker	*Asyndesmus lewis*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Williamson's Sapsucker	*Sphyrapicus thyroideus*
Hairy Woodpecker	*Dendrocopos villosus*
White-headed Woodpecker	*Dendrocopos albolarvatus*
Northern Three-toed Woodpecker	*Picoides tridactylus*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Say's Phoebe	*Sayornis saya*
Hammond's Flycatcher	*Empidonax hammondii*
Dusky Flycatcher	*Empidonax oberholseri*
Gray Flycatcher	*Empidonax wrightii*
Western Flycatcher	*Empidonax difficilis*
Coues' Flycatcher	*Contopus pertinax*
Western Wood Pewee	*Contopus sordidulus*
Olive-sided Flycatcher	*Nuttallornis borealis*
Violet-green Swallow	*Tachycineta thalassina*
Tree Swallow	*Iridoprocne bicolor*
Gray Jay	*Perisoreus canadensis*
Steller's Jay	*Cyanocitta stelleri*
Black-billed Magpie	*Pica pica*
Common Raven	*Corvus corax*
Common Crow	*Corvus brachyrhynchos*
Pinyon Jay	*Gymnorhinus cyanocephala*
Clark's Nutcracker	*Nucifraga columbiana*
Black-capped Chickadee	*Parus atricapillus*
Mexican Chickadee	*Parus sclateri*
Mountain Chickadee	*Parus gambeli*
Bushtit	*Psaltripanus minimus*
White-breasted Nuthatch	*Sitta carolinensis*
Pygmy Nuthatch	*Sitta pygmaea*
Brown Creeper	*Certhia familiaris*
Dipper	*Cinclus mexicanus*
House Wren	*Troglodytes aedon*
Canyon Wren	*Catherpes mexicanus*
Rock Wren	*Salpinctes obsoletus*
American Robin	*Turdus migratorius*
Hermit Thrush	*Hylocichla guttata*
Western Bluebird	*Sialia mexicana*

Mountain Bluebird	*Sialia currucoides*
Townsend's Solitaire	*Myadestes townsendi*
Golden-crowned Kinglet	*Regulus satrapa*
Ruby-crowned Kinglet	*Regulus calendula*
Loggerhead Shrike	*Lanius ludovicianus*
Solitary Vireo	*Vireo solitarius*
Red-eyed Vireo	*Vireo olivaceus*
Warbling Vireo	*Vireo gilvus*
Virginia's Warbler	*Vermivora virginiae*
Lucy's Warbler	*Vermivora luciae*
Olive Warbler	*Peucedramus taenieatus*
Yellow-rumped Warbler	*Dendroica coronata*
Black-throated Gray Warbler	*Dendroica nigrescens*
Townsend's Warbler	*Dendroica townsendi*
Grace's Warbler	*Dendroica graciae*
Red-faced Warbler	*Cardellina rubrifrons*
Northern Oriole	*Icterus galbula*
Brewer's Blackbird	*Euphagus cyanocephalus*
Brown-headed Cowbird	*Molothrus ater*
Western Tanager	*Piranga ludoviciana*
Hepatic Tanager	*Piranga flava*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Evening Grosbeak	*Hesperiphona vespertina*
Purple Finch	*Carpodacus purpureus*
Cassin's Finch	*Carpodacus cassinii*
House Finch	*Carpodacus mexicanus*
Pine Grosbeak	*Pinicola enucleator*
Pine Siskin	*Spinus pinus*
American Goldfinch	*Spinus tristis*
Red Crossbill	*Loxia curvirostra*
Green-tailed Towhee	*Chlorura chlorura*
Dark-eyed Junco	*Junco hyemalis*
Gray-headed Junco	*Junco caniceps*
Mexican Junco	*Junco phaeonatus*
Chipping Sparrow	*Spizella passerina*

Plants

Mexican Pinyon	*Pinus cembroides*
Colorado Pinyon	*Pinus edulis*
Limber Pine	*Pinus flexilis*
White Pine	*Pinus reflexa*
Chihuahua Pine	*Pinus chihuahuana*
Lodgepole Pine	*Pinus contorta*
Rocky Mountain Ponderosa Pine	*Pinus ponderosa scopulorum*
Arizona Ponderosa Pine	*Pinus ponderosa arizonica*
Apache Pine	*Pinus latifolia*
White Spruce	*Picea glauca*
Engelmann Spruce	*Picea engelmani*
Blue Spruce	*Picea pungens*
Douglas-fir	*Pseudotsuga taxifolia*
White Fir	*Abies concolor*
Common Juniper	*Juniperus communis*
Rocky Mountain Juniper	*Juniperus deppeana*
One-seed Juniper	*Juniperus osteosperma*
Bluebunch Wheatgrass	*Agropyron spicatum*
Little Bluestem	*Andropogon scoparius*
Blue Gramma	*Bouteloua gracilis*
Timber Oatgrass	*Danthonia intermedia*
Idaho Fescue	*Festuca idahoensis*
Kentucky Bluegrass	*Poa pratensis*
Blue Wild Rye	*Elymus glaucus*
False-melic	*Shizachne purpurascens*
Ross' Sedge	*Carex rossi*
Elk Sedge	*Carex geyeri*
Quaking Aspen	*Populus tremuloides*
Paper Birch	*Betula papyrifera*
Eastern Hophornbeam	*Ostrya virginiana*
Bur Oak	*Quercus macrocarpa*
Gambel Oak	*Quercus gambeli*
Net-leaf Oak	*Quercus reticulata*
Emory Oak	*Quercus emoryi*
Silverleaf Oak	*Quercus hypoleucoides*
Oregon Grape	*Berberis repens*
Squaw Currant	*Ribes cereum*
Woods Rose	*Rosa woodsii*
Western Serviceberry	*Amelanchier alnifolia*
Cliffrose	*Cowania mexicana*
Oceanspray	*Holodiscus dumosus*

Ninebark
Meadowsweet
Mountain Mahogany
Common Chokecherry
Shrubby Potentilla
(Bush Cinquefoil)
Woodland Strawberry
Squawbush
Boxleaf Myrtle
New Mexican Locust
Rocky Mountain Maple

Bigtooth Maple
Arizona Madrone
Buckbrush
Buckthorn
Silver Buffaloberry
Beaverberry
Tanoleaf Sedstraa
Mountain Snowberry
Common Snowberry
Big Sagebrush
Black Sagebrush

mixed-conifer forest has been, and continues to be, one of the most heavily used for timber resources--a fact that gives this forest type high priority for evaluating the effects of timber management on wildlife resources.

In this report the mixed-conifer forest and its various stand conditions in the Sierra Nevada of California are described, and results of studies of avian communities in this forest type during the breeding season are summarized. Observed composition of avian communities is compared with predictions available in a bird species-habitat association matrix (Verner et al. 1980). This document is hereafter referred to as the "species-habitat matrix" or as the "matrix". It is based on the best information available at this time and displays species' associations with various stand conditions, ranking them as optimum, suitable, or marginal (Table 1). A major purpose of this report is to evaluate the usefulness of the matrix as a tool designed to assist land managers in assessing impacts of land and resource management projects on wildlife. Finally, some of the effects of forest management on bird community composition are discussed, and major conclusions and management recommendations are itemized.

THE MIXED-CONIFER FOREST

The mixed-conifer forest is perhaps the most difficult of Sierra Nevada forest types to define. The classification used here corresponds to that of the Society of American Foresters (1954). Munz and Keck (1965) include the mixed-conifer forest as part of their ponderosa pine forest type, and Rundel et al. (1977) refer to it as the white fir--mixed-conifer forest.

In the Sierra Nevada of California, the mixed-conifer forest type is predominantly a five-species mixture of white fir (Abies concolor), incense-cedar (Libocedrus decurrens), sugar pine (Pinus lambertiana), ponderosa pine (Pinus ponderosa), and Douglas-fir (Pseudotsuga menziesii), the latter species being restricted to the northern half of the Sierra Nevada. The mixed-conifer type is found at elevations from about 4100 to 7200 feet (1250 to 2200 m), depending on latitude (Rundel et al. 1977). Typically, white fir is the dominant species, with incense-cedar and sugar pine as important associates but rarely dominant in a stand. In the northern Sierra Nevada, white fir is much less dominant and Douglas-fir "is the prominent member of the community" (Rundel et al. 1977). Incense-cedar, ponderosa pine, and black oak (Quercus kelloggii) may assume prominence, especially at lower elevations, and on more xeric sites at higher elevations. Above 5500 feet (1675 m), Jeffrey pine (Pinus jeffreyi) generally replaces the ponderosa pine component, and at the upper edge of the mixed-conifer forest, red fir (Abies magnifica) and sometimes lodgepole pine (Pinus contorta) form a transition with the white fir.

Stand structure is highly variable. Soil moisture is a major determinant of stand composition and density, and the rugged terrain clothed by the mixed-conifer forests of the Sierra Nevada results in markedly varied slopes and aspects. This variability, of course, influences drainage and evapotranspiration. Depth, texture, and other qualities of the soil are also diversified, and the often massive granitic outcrops provide growing conditions for plant life that can be unusually challenging. These granitic outcrops, typically, are conspicuous as "bald" spots in the forest. Together with the differing fire histories from site-to-site, these features have the effect of generating highly variable stand structure in the mixed-conifer forest. Uniform stands range in size from a few trees to a few acres or more of trees and represent different stages of successional development. Older trees generally are uniformly dispersed, although younger trees tend to show a clumped pattern of distribution (Bonnicksen 1975).

"Understory trees and shrubs form an important element in white fir [mixed-conifer] forest. The most significant aspects of this understory layer are the dense thickets of white fir and incense-cedar saplings that have developed in this century

in response to decreased fire frequency. Although total understory tree and shrub cover is extremely variable, coverages of 5-10% are common, and values to 30% or more are not unusual" (Rundel et al. 1977:565).

Ground cover, primarily herbaceous, is sparse in the mixed-conifer forest, seldom exceeding 5 percent, "except in moist swales or drainage bottoms" where it may approach 100 percent (Rundel et al. 1977).

Successional Stages and Classes of Canopy Cover

The effect of major disturbance in any forest stand is to reverse succession to an earlier stage. In clearcutting, for example, a site usually is reverted to bare soil, and the soil's structure is altered markedly. The California Wildlife Habitat Relationships Program for the Western Sierra, being developed by the Forest Service's Pacific Southwest Region and the Pacific Southwest Forest and Range Experiment Station, recognizes four seral stages for purposes of cataloging animal use preferences (Verner and Boss 1980). These are as follows:

1. The grass-forb stage invades areas of newly disturbed soil. It consists of annual and perennial grasses and forbs, with or without scattered shrubs and seedlings. It is a short-lived stage, and usually develops into the next stage within 2 or 3 years. If a logged site is prepared and seedlings are planted, this stage may be by-passed altogether.

2. The shrub-seedling-sapling stage supports mixed or pure stands of shrubs, tree seedlings, and saplings up to about 20 feet (6 m) tall. On the basis of site index values for dominant trees in mixed-conifer stands of average basal area in California (Arvola 1978), this stage should last from about 10 to 40 years, depending on site quality.

3. The pole-medium tree stage includes larger trees, ranging in height from 20 to 50 feet (6 to 15 m). On unusually productive sites, this stage might last only about 15 years, and on poor sites it may last up to 90 years. A 40-year life is more likely for the pole-medium tree stage (Arvola 1978).

4. The large tree stage roughly corresponds to the mature and overmature classifications of foresters. Trees generally exceed 50 feet (15 m) in height. Provision for those species of wildlife adapted to this stage is probably best met by stands in excess of 100 years old.

Stages 3 and 4 are subdivided further into three classes of canopy cover. Class A has from 0 to 39 percent canopy cover; class B has from 40 to 69 percent canopy cover; and class C has 70 percent or more canopy cover. "The extent of a shrub layer is paramount in the habitat selection of many animal species, particularly birds. The present classification omits direct reference to percent shrub cover, but the division of successional stages by percent canopy coverage deals indirectly with the question of shrub cover, because the growth of a shrub layer is related to the amount of sunlight able to pass through the canopy" (Verner and Boss 1980). Class A stands typically support a substantial shrub layer; class B stands usually have fewer shrubs; and class C stands normally have few or no shrubs. These relationships are not absolute, however. For example, class A stands on massive granite outcrops generally lack extensive shrub cover, and small patches of shrubs commonly occur in conjunction with temporary openings in the canopy of class C stands. Exceptions such as these require appropriate interpretation in the application of the wildlife habitat associations predicted by the species-habitat matrix.

The system described identifies eight habitat stages in the mixed-conifer forest--1, 2, 3A, 3B, 3C, 4A, 4B, and 4C. Each reflects a different structural

configuration of the stand. A habitat stage, as used here, is a subdivision including habitat type (mixed-conifer forest), successional stage (1, 2, 3, or 4) and canopy cover class (A, B, or C). Obviously other more detailed systems, with more subdivisions, could be designed, but for wildlife assessments it probably is not practical at this time. Available information on habitat preferences of wildlife species of the Sierra Nevada is not sufficient to permit a more precise assignment of species to habitat stages.

THE BIRD COMMUNITIES

Species Composition by Habitat Stage

Few studies of avian communities in the mixed-conifer forests of the Sierra Nevada are available. The Audubon Society's annual Breeding Bird Census, the most likely source for such information, for example, has no reports on this habitat type. In this analysis, therefore, I rely heavily on matrix predictions of species occurrence in the various mixed-conifer habitat stages, as defined earlier. The predictions have been compared with available information from field studies, as a check on their accuracy. Finally, I deal here only with breeding season community composition, partly because published data are available only for that season, and partly because I believe that management of the forest solely with reference to maintenance of all breeding species will provide adequately for migrant and wintering birds as well.

Field studies reported for the mixed-conifer forests on the western slope of the Sierra Nevada include Kilgore's (1968) work in giant Sequoia (Sequoiadendron giganteum) groves in Tulare County, Beedy's (1976) study in the American River drainage, Placer County, and Larson's[1/] extensive work in the Sierra National Forest, Fresno and Madera Counties. Kilgore used the spot-map method (Williams 1936) to census four 20-acre (8.1-ha) sites 3 years each. Results from one of these sites are not included here, because it had a large meadow near one end, which provided considerable forest edge environment. Beedy used a strip-transect method (Kendeigh 1944, Salt 1957) to sample two transects 98.4 feet (30 m) wide and 2100 feet (640 m) and 2707 feet (825 m) long. The sites were sampled weekly from 17 June to 11 September 1974. Beedy[2/] has indicated which of the species he recorded that likely bred on the sites. Larson sampled 52 sites seven times each in 1978 and 1979, by using the variable-diameter, circular plot method (Reynolds et al. 1980). This method does not use a plot of fixed area. Larson's sites included seven of the eight habitat stages identified earlier for the mixed-conifer forest.

Studies on the east slope of the Sierra Nevada, near Sagehen Creek, Nevada County, are reported by Bock and Lynch (1970), Beaver (1972), and Bock et al. (1978). Bock and his associates used the spot-map method to census a 21-acre (8.5-ha) site in 1966, 1967, and 1968 (Bock and Lynch 1970) and again in 1975 (Bock et al. 1978). In the same area, Beaver sampled three 50-acre (20-ha) sites by the spot-map method in 1969, 1970, and 1971. Each of Beaver's sites was in a different habitat stage. Beaver (1972) identified the forest as fitting the yellow pine type of Munz and Keck (1965), a classification that includes the mixed-conifer forest as defined here. Except for the fact that on the east side Jeffrey pine replaces the ponderosa pine usually found in the west slope mixed-conifer forests, the Sagehen Creek forest falls within our definition of a mixed-conifer type, and I treat it as such in this paper.

1/ Personal communication from Terry A. Larson, Illinois State University, December 1979.

2/ Personal communication from Edward C. Beedy, University of California, Davis, December 1979.

Table 1.--Species of breeding birds[1/] in the mixed-conifer forests of the Sierra Nevada of California. Optimum (O), suitable (S), and marginal (M) habitat stages are coded[2/]

Bird Species	Habitat Stages[3/]							
	1 e[4/]	2 ae	3A ae	3B e	3C	4A e	4B ace	4C bde
Goshawk (Accipiter gentilis)				S	M		O	S
Sharp-shinned Hawk (Accipiter striatus)				S	S		S e	S
Red-tailed Hawk (Buteo jamaicensis)	M	M	S e	M		S	M	
Golden Eagle (Aquila chrysaetos)	M	M	M	M	M	M	M	M
Blue Grouse (Dendragapus obscurus)			S	M	M	O	S	M e
Mountain Quail (Oreortyx pictus)		O ae	O	M		O e	M e	d
Chukar (Alectoris chukar)	S	S						
Turkey (Meleagris gallopavo)	S	M	S	M		S	M	
Band-tailed Pigeon (Columba fasciata)			S e	S e	M	S e	S	M de
Mourning Dove (Zenaida macroura)			M	M		M	M	
Flammulated Owl (Otus flammeolus)			S	S	S	S	S	S
Great Horned Owl (Bubo virginianus)			S	S	S	S	S	S
Pygmy Owl (Glaucidium gnoma)			S	S	M	S	S	M
Spotted Owl (Strix occidentalis)			M	M	M	M	S	O e
Great Gray Owl (Strix nebulosa)			M	S	S	M	S	O

Table 1.--(cont'd)

Bird Species	Habitat Stages							
	1 e	2 ae	3A ae	3B e	3C	4A e	4B ace	4C bde
Saw-whet Owl (Aegolius acadicus)				O	S		O	S
Poor-will (Phalaenoptilus nuttallii)	O	O	S a	M		S	M	
Common Nighthawk (Chordeiles minor)	O	S	M			M	e	
Vaux's Swift (Chaetura vauxi)						S	S	S
Calliope Hummingbird (Stellula calliope)		e	O ae	S		O e	S ae	
Common Flicker (Colaptes auratus)			S e	M	M	O e	S ce	M bd
Pileated Woodpecker (Dryocopus pileatus)						S e	O e	O bd
Yellow-bellied Sapsucker (Sphyrapicus varius)			S e	S		O e	O ace	bde
Williamson's Sapsucker (Sphyrapicus thyroideus)			a			e		
Hairy Woodpecker (Picoides villosus)	e	e	e	e		O e	O ace	bd
White-headed Woodpecker (Picoides albolarvatus)	e	e	e	M e		S e	O ace	S bde
Black-backed Three-toed Woodpecker (Picoides arcticus)							ac	
Hammond's Flycatcher (Empidonax hammondii)				M	S		O e	O bde
Dusky Flycatcher (Empidonax oberholseri)		O ae	O ae	S e		O e	S ac	
Western Wood Pewee (Contopus sordidulus)		e	S e	S e	M	O e	O ace	S bde
Olive-sided Flycatcher (Nuttallornis borealis)			ae	e		O e	S e	M bde

Table 1.--(cont'd).

Bird Species	Habitat Stages							
	1 e	2 ae	3A ae	3B e	3C	4A e	4B ace	4C bde
Violet-green Swallow (Tachycineta thalassina)	O	O	O	S	S	O	S	S
Steller's Jay (Cyanocitta stelleri)			S e	S e	M	O e	O ace	S bde
Common Raven (Corvus corax)	S	S	S	S	S	S	S	S
Mountain Chickadee (Parus gambeli)	e	e	S ae	S e	S	O e	O ace	S bde
Chestnut-backed Chickadee (Parus rufescens)						M	O	O
White-breasted Nuthatch (Sitta carolinensis)			M a	M	M	S e	S ac	M b
Red-breasted Nuthatch (Sitta canadensis)			a	S e	S	e	S ace	O bde
Pygmy Nuthatch (Sitta pygmaea)						S	S	
Brown Creeper (Certhia familiaris)				e		e	S ace	O bde
Winter Wren (Troglodytes troglodytes)							S	O de
American Robin (Turdus migratorius)			O ae	S e	S	O e	S ace	S bde
Hermit Thrush (Catharus guttatus)			M	O e	O	M e	O ace	O bde
Swainson's Thrush (Catharus ustulatus)				M	S		M	S
Western Bluebird (Sialia mexicana)	M	M	M e	M		M	M	
Mountain Bluebird (Sialia currucoides)	M e	M e	M ae	M		M	M	
Townsend's Solitaire (Myadestes townsendi)			O e	S e	M	O e	S ace	M bde

Table 1.--(cont'd)

Bird Species	Habitat Stages							
	1	2	3A	3B	3C	4A	4B	4C
	e	ae	ae	e		e	ace	bde
Golden-crowned Kinglet (Regulus satrapa)				S e	S	e	O ace	O bde
Ruby-crowned Kinglet (Regulus calendula)			M	M		M	M	b
Solitary Vireo (Vireo solitarius)			O	S	M	O	S ace	M bde
Warbling Vireo (Vireo gilvus)			O e	S e	M	O e	S e	M de
Nashville Warbler (Vermivora ruficapilla)		S ae	O a	S		O e	S ace	bd
Yellow Warbler (Dendroica petechia)		M ae	M a	M	M	M	M	M b
Yellow-rumped Warbler (Dendroica coronata)		M e	O e	S e	S	O e	S ace	S bde
Hermit Warbler (Dendroica occidentalis)			M e	S e	S	O e	O e	S bde
MacGillivray's Warbler (Oporornis tolmiei)		O e	O	S		O e	S e	e
Common Yellowthroat (Geothlypis trichas)		S	S	S	S	S	S	S
Wilson's Warbler (Wilsonia pusilla)		O	O a	S	M	O e	S	M e
Brewer's Blackbird (Euphagus cyanocephalus)	M	M	M			M		
Brown-headed Cowbird (Molothrus ater)	M	M e	M e	M e	M	M e	M e	M b
Western Tanager (Piranga ludoviciana)			ae	e		M e	O ace	S bde
Black-headed Grosbeak (Pheucticus melanocephalus)			S	M		S	M e	M de
Lazuli Bunting (Passerina amoena)	M	M ae	M			M		

Table 1.--(cont'd)

Bird Species	Habitat Stages							
	1 a	2 ae	3A ae	3B e	3C	4A e	4B ace	4C bde
Evening Grosbeak (Hesperiphona vespertina)						M e	O a	S d
Purple Finch (Carpodacus purpureus)			M	S	S	M e	O e	O
Cassin's Finch (Carpodacus cassini)			a	e		M e	M ace	e
Unidentified Finch (Carpodacus sp.)								bd
Pine Siskin (Carduelis pinus)			S e	M	M	S e	M ae	M
Green-tailed Towhee (Pipilo chlorurus)		O ae	S ae			S e	e	
Rufous-sided Towhee (Pipilo erythrophthalmus)		M e	M			M e	e	d
Dark-eyed Junco (Junco hyemalis)		S ae	O ae	S e	M	O e	S ace	S bde
Chipping Sparrow (Spizella passerina)		e	O ae	S e		O e	S ae	b
Brewer's Sparrow (Spizella breweri)		a						
nned Sparrow la atrogularis)		M						
ow ella iliaca)		O ae	O ae	M e		O e	M ace	be
Sparrow iza lincolnii)		O	S	S	S	S	S	S

sic list largely from Verner et al. (1980) for the Western Sierra Nevada; dies added Williamson's Sapsucker, Black-backed Three-toed Woodpecker, and Sparrow, as explained in the text. Species with special habitat require- ponds, lakes, rivers, streams, or cliffs are omitted here, because changes stand structure generally do not affect site suitability on the basis of

Table 1.--(cont'd)

2/Habitat capability classes optimum, suitable, and marginal are based on relative densities of breeding populations. They necessarily represent judgments of the authors (Verner et al. 1980) and so are subjective. As more data accumulate, we hope these qualifiers can be assigned on more objective terms, such as optimum in habitats where reproduction generally results in surplus individuals (r is positive), suitable where reproduction generally results in population maintenance (r is zero), and marginal where reproduction generally is insufficient to maintain the population (r is negative).

3/Habitat stages are as follows: 1 - grass-forb; 2 - shrub-seedling-sapling; 3A - pole-medium tree, 0-39 percent canopy cover; 3B - pole-medium tree, 40 to 69 percent canopy cover; 3C - pole-medium tree, 70 percent or more canopy cover; 4A - large tree, 0 to 39 percent canopy cover; 4B - large tree, 40 to 69 percent canopy cover; 4C - large tree, 70 percent or more canopy cover.

4/Lower case letters identify breeding bird censuses in these habitat stages, as follows: a - Beaver 1972, b - Beedy 1976, c - Bock and Lynch 1970, Bock et al. 1978; d - Kilgore 1968, e - Larson (in prep.).

Seventy-two bird species are predicted by the species-habitat matrix to breed in various habitat stages of mixed-conifer forests in the western Sierra Nevada (Table 1). Relative suitability of each habitat stage is identified for each species, and species detected in each of the field studies cited earlier are also coded in the table. The list does not include species with aquatic or cliff requirements for breeding, because changes in forest stand structure generally do not affect site suitability on the basis of those special requirements. Because matrix information forms the core of my analysis here, it is worth examining more closely the agreement between it and results of field studies. It should be noted that Beedy's (1976) data reported here were also used in preparation of the species-habitat matrix.

Three species detected in field studies but not predicted as breeders in the mixed-conifer forests of the western Sierra Nevada have been included in Table 1, in addition to the 72 species predicted by the matrix. One, the Brewer's Sparrow, was reported by Beaver (1972) in a shrub-stage site on the east side. Another, the Williamson's Sapsucker, was reported nesting in stages 3A (Beaver 1972) and 4A,1/ and may represent an error in predictions of the species-habitat matrix. The third species is the Black-backed Three-toed Woodpecker reported in stage 4B stands on the east side (Bock and Lynch 1970, Beaver 1972). Adjacent to their sites, an intense fire burned about 40,000 acres (15,800 ha) of timber in 1960 (Bock and Lynch 1970). Black-backed Three-toed Woodpeckers are known to be attracted to areas of burned timber, and Granholm3/ located their nests in two recent, intensely burned mixed-conifer sites in Yosemite National Park. This species finds optimum nesting habitat at higher elevations in the western Sierra Nevada, in lodgepole pine and red fir forests. It appears, however, that it will nest at lower elevations, in the mixed-conifer zone, if fire creates suitable conditions.

The matrix codes some habitats as optimum for some species, suitable for some, and only marginal for still others. If the matrix predictions are reasonably accurate, field studies should detect a higher proportion of species in optimum habitat stages than in suitable, and a higher proportion in suitable than in marginal

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3/ Personal communication from Stephen L. Granholm, University of California, Davis, December 1979.

sites. To test this I have eliminated from consideration those species on the matrix list that we might not expect field workers to find breeding on their plots, as follows:

a. All owls, because sampling methods were not designed to detect them.

b. Falconiformes, because their territories are so large as to minimize the chance that a nest would be located on a study plot.

c. The Common Raven, because it typically nests on cliffs, and no study site included cliffs.

d. The Chukar, Turkey, Chestnut-backed Chickadee, and Black-chinned Sparrow because their restricted distributions were not included in any study site.

e. The Common Yellowthroat and Lincoln's Sparrow, because they typically nest in very wet sites not included in any of the study plots.

Taking all habitat stages together, the various field studies collectively reported 81 percent of the predicted species in optimum habitat, 66 percent in suitable habitat, and 53 percent in marginal habitat. This trend was evident in only six of the 14 studies considered singly, but in 13 of 14 the highest percentage of species was detected for optimum habitat (Table 2).

If combined results of the field studies are considered, in 40 cases various species were detected as breeders in habitat stages not predicted by the matrix. Because this number represents 20 percent of the combined sample, it may suggest that the matrix is less accurate than desired. The matrix was designed in reference to relatively large stands of the various habitat stages, however, and the mixed-conifer zone of the western Sierra Nevada tends to be a patchwork of large and small stands intermixed in a heterogeneous whole. If each exception to a matrix prediction is examined in terms of the bird species' habitat requirements, 31 of the 40 exceptions can be resolved in terms of present matrix predictions. In stages 4B and 4C, for example, openings associated with such things as rock outcrops or fallen trees result in small patches of shrubs. These may attract such breeding species as Mountain Quail, Nashville Warbler, MacGillivray's Warbler, Green-tailed Towhee, Rufous-sided Towhee, Chipping Sparrow, and Fox Sparrow. A large rock outcrop in one 4B stand apparently attracted a pair of Common Nighthawks[1/]. Scattered, large trees left standing in stages 2, 3A, and 3B may explain detection there of the Olive-sided Flycatcher, Red-breasted Nuthatch, Brown Creeper, Western Tanager, and Cassin's Finch.

In general, the percentages of predicted breeding species detected in field studies increased with advancing seral development of a site, with stage 1 sites producing the greatest departure from matrix predictions (Table 2). These sites, resulting from clearcutting, did not develop substantial grass-forb cover, and the only species nesting in them were the Hairy Woodpecker, White-headed Woodpecker, Mountain Chickadee, and Mountain Bluebird. The woodpeckers excavated their own nest cavities in stumps less than 5 feet (1.5 m) high, and bluebirds and chickadees nested in cavities excavated by the woodpeckers[1/]. These same species also exploited stumps for nest cavities in stages 2 and 3.

Figure 1A graphs the mean numbers of bird species noted in field studies in the different habitat stages, and Figure 1B shows the matrix predictions for each habitat stage, subdivided according to optimum, suitable, and marginal habitat capabilities. The general patterns of increasing numbers of species with advancing seral development depicted by these histograms are similar, and they are in general agreement with other studies of avian communities in relation to succession in a wide variety

of forest types in many different areas--northern California (Hagar 1960), Oregon (Meslow and Wight 1975), Michigan (Adams 1908), Illinois (Karr 1968), Arkansas (Shugart and James 1973), Maine (Titterington et al. 1979), New York (Kendeigh 1946), Virginia (Conner and Adkisson 1975), Georgia (Johnston and Odum 1956), Finland (Haapanen 1965), Poland (Glowacinski 1975), and Germany (Dierschke 1973). Some of these studies show a decline in species numbers associated with mature to old-growth stands, a trend also suggested in Figure 1B in connection with higher percentage canopy cover.

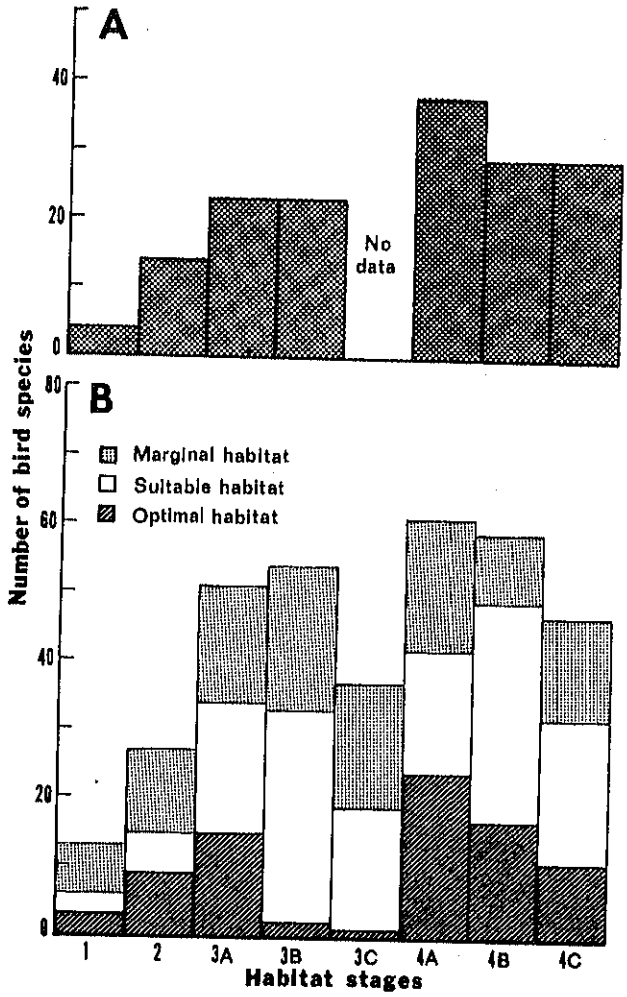

Figure 1.--Breeding birds of mixed-conifer forests of the Sierra Nevada. The upper histogram (A) depicts mean numbers of breeding bird species detected in different habitat stages by various workers, cited in Table 2. The lower histogram (B) depicts predictions of the species-habitat matrix, subdivided according to the numbers of species finding optimum, suitable, and marginal habitat in the different habitat stages.

The various comparisons of field results and the information in the species-habitat matrix, taken together, provide strong support for the accuracy of the matrix as a predictive tool in assessing effects of land-use projects in mixed-conifer forests of the western Sierra Nevada.

Determinants of Avian Community Composition

The National Forest Management Act of 1976, referring to multiple-use management, explicitly mandates that diversity of plant and animal species be maintained. Peet (1975) provides a detailed evaluation of the concept of species diversity. It is sufficient for this paper simply to note that computations of species diversity indices require data on species richness (the number of species in the community) and species evenness (the relative abundanc of the species). The index most often used for species diversity in studies o. avian communities is Shannon's function[4/]. Because Tramer (1969) showed a high correlation (r = 0.97) between diversity and richness of bird species, it may be just as valid to gear management toward species richness as toward species diversity. And it is considerably more practical, as determination of the number of bird species in a given area is more accurate and less time consuming than determination of the abundance of each species.

4/ $H' = \sum_{i=1}^{s} P_i \log_2 P_i$, where P_i is the proportion of individuals in the i-th species (i = 1, 2, 3, ..., S) (Shannon and Weaver 1963).

Table 2.—Concurrence of field counts and species-habitat matrix predictions of breeding birds in mixed-conifer forests of the Sierra Nevada.

Habitat stage (number sites; number years sampled)	Number of matrix-listed species detected in the field			Number of detected species not predicted by matrix	Total species detected	Estimated total density[1] (prs/100 acres)	References
	Optimum habitat	Suitable habitat	Marginal habitat				
1 (2;2)	0 (0)[2]	0 (0)[2]	1 (14)[2]	3 (75)[2]	4		Larson (In prep.)
2 (1;3)	4 (44)	2 (33)	2 (17)	2 (20)	10	139	Beaver 1972
2 (15;2)	4 (56)	2 (33)	6 (50)	6 (32)	18		Larson (In prep.)
3A (1;3)	8 (53)	3 (16)	3 (19)	6 (30)	20	85	Beaver 1972
3A (6;2)	9 (60)	9 (47)	4 (25)	4 (15)	26		Larson (In prep.)
3B (1;2)	1 (50)	14 (44)	3 (15)	5 (22)	23		Larson (In prep.)
4A (14;2)	21 (88)	6 (33)	6 (33)	5 (13)	38		Larson (In prep.)
4B (1;3)	10 (59)	12 (38)	3 (30)	1 (4)	26	111	Beaver 1972
4B (1;4)	9 (53)	11 (34)	2 (20)	1 (4)	23	91	Bock and Lynch 1970, Bock et al. 1978
4B (10;2)	13 (76)	15 (47)	6 (60)	3 (8)	37		Larson (In prep.)
4C (2;1)	7 (64)	9 (38)	7 (47)	5 (18)	28	251	Beedy 1976
4C (3;3)	8 (73)	10 (48)	7 (47)	5 (17)	30	267	Kilgore 1968
4C (4;2)	7 (64)	9 (43)	8 (53)	4 (14)	28		Larson (In prep.)

[1] Values are means of multiple sites, or count years, or both.
[2] Percentages shown in parentheses.

MacArthur et al. (1962) concluded that "The main reason one habitat supports more bird species than another is that the first has a greater internal variation in vegetation profile (that is, a greater variety of different kinds of patches). A second reason is of course that a forest with vegetation at many heights above the ground will simultaneously support ground dwellers, shrub dwellers and canopy dwellers. With a few exceptions, the variety of plant species has no direct effect on the diversity of bird species." Research after publication of this statement generally agrees. Bird species richness tends to increase with increasing horizontal heterogeneity of the vegetation (patchiness) and with addition of layers of vegetation (shrubs, trees).

MacArthur and MacArthur (1961) pioneered in the quantitative assessment of bird species diversity and the use of diversity indices to compare different communities. Their studies show that bird species diversity in temperate regions is correlated with foliage height diversity. The more layers of foliage in the vegetation, and the more evenly the layers are distributed vertically, the higher will be the bird species diversity. Many workers following the assessment of MacArthur and MacArthur (1961) found support for this relationship, even in such simple communities as grasslands (Cody 1968). I agree with Balda (1975) that foliage height diversity is one of the best predictors of bird species diversity measured to date, but several studies have failed to show a significant correlation between these variables in some localities (Balda 1969, Terborgh and Weske 1969, Carothers et al. 1974, Wiens 1973, 1974; Tomoff 1974, Willson 1974, Pearson 1975, Roth 1976, and Young 1977).

Other important features of vegetation structure that apparently influence bird species diversity in at least some habitats include horizontal heterogeneity--that is, patchiness (Blondel et al. 1973, Wiens 1973, 1974, Roth 1976), percentage of vegetation cover (Karr and Roth 1971, Willson 1974), and foliage volume (Balda 1969, Pearson 1971). Young (1977) found a correlation between the diversity of tree diameter classes (DBHD) and bird species diversity in aspen and spruce-fir communities in Utah. Further, "DBHD was correlated with DD [distance diversity], a measure of tree dispersion and density or horizontal heterogeneity. It was also an indirect measure of vertical heterogeneity since tree DBH was correlated with tree height and canopy radius. DBHD also was a measure of the variability of tree life forms because the DBH values were sorted by tree species. DBHD was therefore an index of three dimensional environmental patchiness." This relationship deserves further study, because DBH values are measured regularly in forests, and they can be taken quickly and accurately.

In a few cases, plant species diversity has been found to make a significant contribution to bird species diversity (Karr 1968, Balda 1967, Tomoff 1974). Certain plant species dependencies of birds are important to bird species richness, as with frugivores and nectarivores (see Karr 1971, Feinsinger 1976, Terborgh 1977). In mixed-conifer forests of the Sierra Nevada, Beedy (1976) believes that the presence of Jeffrey pines or black oaks in a stand influer

to know much more than the bird species diversity of any stand. We must know which species presently use the stand, how they use it, what their approximate densities are, and how they likely will respond to changes in the vegetation of the stand. We must also be able to show that losses resulting from a given management action either are not significant or are being compensated for by gains elsewhere. It will not be possible to avoid looking rather closely at the habitat requirements of individual species and the ways in which the species exploit their environments. The species-habitat matrix is a first attempt at assembling some of the information required by the land manager to do this.

BIRDS AND FOREST MANAGEMENT

Effects on Vegetation

Timber harvest, unquestionably, has the greatest impact of all human influences on mixed-conifer forests of the Sierra Nevada of California. Four basic silvicultural systems are used. Three of these--clearcutting, seed-tree cutting, and shelterwood cutting--result in even-aged stand management. The fourth--selection cutting--is intended to result in uneven-aged stand management. Research on this system, however, indicates that for several reasons it fails to achieve the desired results[5/]. Variations of these systems are possible, and special types of cuttings, such as thinnings and sanitation-salvage harvests, also occur. Each system alters the structural configuration and species composition of vegetation in the stand. Knowledge of how a given silvicultural system will change a stand, and what course secondary succession will take on the site, together with available information on bird communities and the various bird species' habitat needs, should allow the forest manager to predict most of the changes in the bird community over time.

The general result of any timber harvest system is to open up the forest canopy, letting more light reach the forest floor, and permitting the growth of grasses, forbs, and shrubs. The greater the extent of canopy removal, of course, the greater this effect will be. Timber harvest changes a stand to an earlier successional stage, or to one with reduced canopy cover, or both. A selection cutting, for example, might change a 4C stand (large tree stage, 70 percent or more canopy cover) to a 4A stand (large tree stage, 0 to 39 percent canopy cover). Bird species richness should increase (Fig. 1), with 17 species finding less suitable habitat and 43 finding more suitable habitat as a result of the change (Table 1). Eleven of the 17 species (65 percent) negatively affected find optimum habitat in the 4C stand, and 24 of the 43 species (56 percent) positively affected find optimum habitat in the 4A stand. About 15 of the positively affected species respond to increased shrub cover, another 12 find more favorable visibility or mobility for seeking prey, and still others respond to a combination of these changes, or to the making of edge-like conditions, or both.

This may seem to be, overall, a beneficial change from the standpoint of the bird community, but examination of the species affected leads to a different conclusion. Two negatively affected species, the Goshawk and Spotted Owl, are classified as "sensitive", and two others, the Great Gray Owl and Pileated Woodpecker, are classified as "special interest" species by the Forest Service, U.S. Department of Agriculture, Pacific Southwest Region. Sensitive species are given the same management emphasis as are Threatened and Endangered Species on State and Federal lists. The possibility of negatively affecting such species may outweigh the possibility that more species are positively affected than negatively affected by the hypothetical selection cutting. Certainly a biologist should carefully search the relevant

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5/ Personal communication from Douglass F. Roy, Pacific Southwest Forest and Range Experiment Station, Redding, California, November 1979.

compartment to determine whether any of the emphasis species are actually present in the area. Based on results of that survey, then, the forest manager must consider carefully the predictions of a wildlife assessment, based on the species-habitat matrix, before reaching a decision on any such proposed timber harvest.

Similar simplistic comparisons may be made of any other possible pair of habitat stage changes resulting from activities such as timber harvest, road construction, site conversion, or herbicide application. To do so, the manager must be able to predict the kinds of changes expected in vegetation structure and to relate these to information available in the bird species-habitat matrix.

Evaluation of the effects on bird communities of modern forest management practices in mixed-conifer forests of the Sierra Nevada might best be made in reference to bird communities in pristine conditions, that is prior to extensive European settlement of California commencing about the middle of the last century. Fires started by lightning and Indians were the principal influences altering the structure and species composition of pristine forests. Preliminary studies of fire frequency in mixed-conifer forests of the Sierra Nevada at that time indicate that a given area sustained a burn on the average of once every 8 years, with a range from 4 to 20 years (Kilgore 1973). That was frequent enough to prevent accumulation of sufficient ground fuels to support the extensive crown fires so familiar to us today. Prior to this century, these frequent and widespread surface fires maintained the mixed-conifer forest in an open, park-like condition (Biswell 1959, 1961). Fire-resistant and fire-dependent species were favored, so that pines dominated the canopy, whereas firs are dominant in today's forest.

Show and Kotok (1924) characterized the pristine pine forests in California during the early part of the 1900's as being patchy and broken, in stands that were "uneven, or at best even-aged by small groups... Local crown fires may extend over a few hundred acres, but the stands in general are so uneven-aged and broken and have such a varied cover type that a continuous crown fire is practically impossible." The same statement probably applies to the mixed-conifer type. Egeline (1980) believes the pristine forest was predominantly in an open-canopied, park-like condition comparable to stage 4A. Development of a shrub understory would be significantly affected by frequent ground fires, such that extensive stands of large, overmature shrubs likely were uncommon, and litter accumulation was minimal. Smaller patches of younger shrubs of fire-tolerant or fire-dependent species probably were the rule. This view contrasts sharply with the stereotype some have of the forest as in a 4C condition, with significant litter accumulation and little shrub understory. Given this picture of the forest prior to modern practices of timber harvest and effective fire suppression, the general pattern of species numbers by habitat stage shown in Figure 1B makes considerable sense.

In terms of the numbers of bird species evolved to exploit the various habitat stages, Figure 1B shows an increasing number of species with advancing seral development through stage 3B, with a marked drop in stage 3C, which we can visualize as dense stands of small-diameter trees 20 to 50 feet (6.1 to 15.2 m) high. Considering only those species finding optimum conditions in the various stages, stages 1, 3B, and 3C are conspicuous as forest stand structures to which few species have become well adapted. Stage 1 is short-lived, developing in a couple years into stage 2. Moreover, if intense crown fires were infrequent, stage 1 conditions would also be infrequent. Stages 3B and 3C, with their smaller trees and denser canopies, would be vulnerable to crown fires and thus likely were not abundantly represented in the pristine forest.

More bird species find conditions for breeding optimum or suitable in stages 4A and 4B than in any other stage. Furthermore, Table 1 shows that, taken together, stages 4A, 4B, and 4C provide optimum breeding habitats for 40 species, but

stages 1 through 3C provide optimum conditions for only 21 species. Seventeen of those species find optimum habitats in both groups of habitat stages (1 through 3C, and 4A through 4C), so only four are restricted to the earlier stages for optimum breeding sites, but 23, or 31 percent of the species listed (Table 1), find optimum sites only in stages 4A, 4B, or 4C. Consider next those species finding optimum breeding conditions in only one habitat stage. Stage 1 has one; stage 2 has two, stages 3A, 3B, and 3C have none; stage 4A has three; stage 4B has four, and stage 4C has five. Again this imbalance in favor of the oldest successional stages argues strongly for these stages as being the most prevalent in mixed-conifer forests of the Sierra Nevada before humans began to harvest timber and exercise some control over wildfires.

Species with strong shrub orientation in their habitat selection could find their needs well satisfied in stages 2, 3A, and 4A, and perhaps even in stages 3B and 4B. Thus they should be expected to occur over a broader spectrum of habitat stages than species with a primary orientation for large trees.

It is not possible, of course, to translate the preceding analysis into an estimate of the proportions of pristine forests in each habitat stage. Consider, however, the facts that (a) 31 percent of the species listed in Table 1 find optimum breeding conditions only in mature to old-growth forests, and (b) 15 species find optimum conditions in only one habitat stage, and 12 (80 percent) of those find them either in stage 4A, 4B, or 4C. On the basis of this imbalance in the proportion of species specialized for mature to old-growth forest conditions, it seems reasonable to conclude that at least a third of the pristine forest acreage in the mixed-conifer zone was in a mature to old-growth condition. Perhaps even as much as half was in that condition.

Effects on Special Habitat Requirements

Information derived from the species-habitat matrix for the western Sierra Nevada, as contained in Table 1, does not account for certain special requirements of birds. These requirements are handled in a different manner in the matrix, and some of these special requirements deserve separate treatment in this report.

SNAGS

Snags are variously defined by different authors, but generally they are dead or partly dead trees that can be expected to provide for excavation of nesting or roosting cavities, or both, bark and wood feeding, and perching by a number of bird species partially or totally dependent on snags at some time of the year.

Three papers in this workshop specifically address the importance of snags and their management in relation to bird communities. It is unnecessary, therefore, to discuss snags in detail in this paper. It is important to emphasize, however, that a viable snag retention policy needs to be observed throughout timber harvest operations. It is a policy of the Forest Service's Pacific Southwest Region to provide "one snag per acre, 11 inches dbh or greater, 12-feet high or higher, in all forest types, plus one-half snag per acre, 16 inches dbh or greater, 12-feet high or higher, in all forest types except lodgepole pine. These densities may represent an average over a project area or compartment, but retained snags shall be distributed in locations best suited for wildlife use. All snags shall be felled that are a hazard to project operations[6/]." I consider these values minimal to provide adequately for snag-dependent species, but more research is needed on this subject.

6/ Interim Directive 5, 2405.14--Wildlife Management (FSM 2600), Calif. Region, Forest Service, U.S. Dep. Agric., San Francisco, Calif., September 21, 1978.

Twenty-three species listed (31 percent) nest in cavities in trees, typically in snags, and many of these also seek shelter in cavities at other times of the year (Table 1). More importantly, 15 of these species spend the winter in the Sierra Nevada mixed-conifer zone and 12 (80 percent) are insectivores. Only 14 species that can be regarded as primarily insectivores are present in significant numbers during winter months in the mixed-conifer forest, therefore, 86 percent of the important winter insectivores depend on snags at some time in their life cycles. As Balda (1975) points out, "During the winter, insect densities are obviously low and presumably the birds are eating hibernating adult insects, larvae, and eggs. It is very likely that the wintering birds are exerting more control on the insect populations at this time than they do in other seasons, as potential breeders are being harvested at this time. Thus, the importance of this nesting guild becomes immediately obvious."

Beebe (1974) reviewed the extensive literature on the impact of birds on populations of injurious insects, citing numerous studies that show the importance of cavity-nesting species in reducing insect populations over the winter. The importance of this effect to forest management is perhaps best documented by the ambitious program of artificial nest-box placement in managed forests of Europe. In Spain, to cite one example, more than 400,000 nest-boxes were placed in an area of about 345,000 acres (140,000 ha), with an additional 300,000 planned (Molina 1971). This amounts to approximately two nest-boxes per acre, undoubtedly involving considerable expense for materials and labor. Forest managers in this country might wish to weigh this alternative against the costs of maintaining adequate numbers of suitable snags.

LITTER

In pristine forests fallen trees, fallen dead branches, dead shrubs, forbs, and grasses accumulate as litter on the ground, where they gradually decay. Elton (1966) estimated that perhaps 20 percent or more of the fauna of a British woodland depends on dead and down woody material. Thomas (1979: Appendix 24) lists 116 bird species that make some use of downed logs in the Blue Mountains of Oregon and Washington. This is an impressive list, even though not all of the species must have downed logs to survive and reproduce. In mixed-conifer forests of the Sierra Nevada, litter provides important foraging sites for at least eight of the 75 bird species (11 percent) listed in Table 1. For some, such as the Winter Wren, large accumulations of litter can provide important nesting cover. In addition, many raptors feed extensively on amphibians, reptiles, and ground-dwelling small mammals that depend on accumulations of forest litter. However, no systematic study of the importance of litter to wildlife has yet been made in the Sierra Nevada.

Current practices sometimes result in significant loss of litter. A prudent blend of slash and litter disposal practices--including burning, scattering, piling, and wind-rowing--probably can be designed to meet the needs of both timber management and wildlife resources. Maser et al. (1979) present an excellent overview of the importance of dead and down woody material to wildlife in the Blue Mountains. Pending availability of research in California, the Blue Mountains paper may serve as a reasonable guideline for forest managers in the Sierra Nevada.

Effects of Patch Size and Dispersion

Selection of the appropriate sizes and dispersion of patches of different habitat types is among the most important elements in developing guidelines for managing bird communities. Unfortunately, however, no systematic studies of this question have yet been published for coniferious forests of the western United States. Thomas et al. (1979) present an imaginative, cogent analysis of patch size and dispersion in relation to edge effects. Space precludes a summary of their paper here, but it is "must" reading for managers involved in planning for wildlife benefits.

Thomas et al. (1979) recommend an average stand size of 84 acres (34 ha) in the Blue Mountains of Oregon and Washington, recognizing that smaller patches would suffice for species with modest area requirements and patches larger than average hopefully would accommodate species requiring large areas. The 84-acre figure is based on the work of Galli et al. (1976) in hardwood forest remnants in an agricultural setting on the New Jersey Piedmont. There, stands of trees are separated by intervening fields. In effect they are three-dimensional islands in a two-dimensional sea. The situation in western conifer forests may differ considerably, because patches often are clearcuts in secondary seral stages advancing toward forest stands again. That is, they are two-dimensional islands in a three-dimensional sea, where the impact of surrounding forest conditions on the avian community in the patch may be quite different from that of the surrounding agricultural lands on remnant hardwood stands in New Jersey.

Other studies in eastern hardwood forests indicate that preserves of "thousands of square kilometers" may be essential for long-term survival even of some bird species with very small territorial requirements (Whitcomb et al. 1976). In another study, Willis (1974) found that from the time Barro Colorado Island was isolated from the mainland by construction of the Panama Canal in 1910-14, at least 13 species of forest birds had disappeared from the island by 1970. This island is only 1650 feet (500 m) from the mainland, and it supports a forest of 3700 acres (1500 ha)! Species no larger than our Red-winged Blackbird (Agelaius phoeniceus) were among those that became extinct on Barro Colorado Island.

Whether or not effects of patch size on population stability are comparable between western coniferous forests and eastern hardwood forests, or tropical Barro Colorado Island, is unknown. My sometimes-faulty intuition tells me that the situations probably are not comparable, because forest management in the west is not creating three-dimensional islands in a two-dimensional sea. Rather it tends to create a mosaic of forest stands of different age classes and stem densities, with occasional, small clearcuts that soon begin to regenerate another stand of timber. Table 1 shows that most species are reasonably flexible in their capacity to utilize several habitat stages. Most species find suitable or better conditions in at least two stages of the mixed-conifer forest, and most successfully utilize other forest types as well. Those species in the table that find only marginal conditions in the mixed-conifer type find better conditions in forest types at higher or lower elevations. Thus, for any given species, effective patch size cannot be measured in terms of one habitat stage. It often will be possible to combine adjacent patches of different stages when both types suit the species in question. Moreover, it is necessary in this connection to broaden our perspectives to include all forest types--to manage within the confines of the mixed-conifer type is to wear blinders. Given these possibilities, then, I find the recommendation for an average patch size of 84 acres (Thomas et al. 1979) to be in harmony with my intuition. However, this obviously is a topic badly in need of research.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Conclusions

Information contained in the bird species-habitat matrix for mixed-conifer forests of the western Sierra Nevada appears to be in close agreement with results of field studies. In the development of project and land management plans, forest biologists and managers need to use the predictions possible from the matrix to assess potential effects on birds. This process is being facilitated with the development of computer applications (Salwasser et al. 1980).

In general it seems reasonable to conclude that modern forest management practices, including development of effective fire suppression measures, have created some fundamental differences in stand structure and species composition between pristine and contemporary forests. Contemporary mixed-conifer forests probably include a higher proportion of stage 4C stands, but a lower proportion of stages 4A, 4B, and 4C taken together. The pine species no doubt comprise a smaller proportion of forest stands today than in the past, with fir and incense-cedar assuming more prominence. The substantial accumulation of dead and down woody material in contemporary forest stands represents a marked contrast with conditions even as recently as the 1920's. These changes probably have not changed the species richness of breeding birds in mixed-conifer forests of the Sierra Nevada, but undoubtedly the relative abundances of many species have undergone marked changes. Species favored by 4C stands are probably more common today, while those favored by 4A stands are probably less common than in the past. Species with a strong shrub orientation are probably more common now than in the past.

The major change with which I believe we need to be most concerned is the reduction in the amount of forest in mature to old-growth conditions. If this trend were to continue, it would no doubt result in serious declines in populations of many breeding bird species of mixed-conifer forests of the Sierra Nevada of California. It is encouraging that the Forest Service's Pacific Southwest Region recently funded a long-term study in California forests of old-growth wildlife and their habitat needs. The study will get underway this spring. It should provide answers to a number of questions critical to formulation of effective guidelines for management of the mature and old-growth habitat stages.

Recommendations

The following recommendations, if followed, should help to maintain stable populations of all bird species in mixed-conifer forests of the Sierra Nevada of California. It is not a general goal to manage these forests for the maximum benefit of birds, although that might be a goal in certain areas. Some of the recommendations, especially the first two, are intended to reduce the complexity of considering the total array of all species' requirements, while at the same time not jeopardizing the needs of any species. The remainder relate directly to maintaining bird populations in a healthy condition. I believe all of the recommendations can be satisfactorily met within the constraints of the needs of other resources, although compromises obviously will be required.

- The emphasis in development of management guidelines for birds should be given to breeding species. Wintering and migrant species use the same habitats that accommodate breeding species. If we continue to provide adequately for the breeders, I believe the requirements of migrants and wintering forms will be met as well.

- Management should emphasize the needs of those species finding optimum and suitable habitats in the mixed-conifer forest. Use of marginal sites likely does not contribute significantly to maintenance of a given species' numbers.

- The concepts of species diversity and species richness are useful as general guidelines for management planning, but management should not settle for the trap of "maximizing species diversity." The needs of all species must be accommodated, and particular attention should be given to those species with limited ecological tolerance--those able to breed in only one or two habitat stages.

- At least 20 percent of each compartment in mature and 20 percent in old-growth stands should be retained.

- A 100-year rotation should be considered minimum, and in those stands managed to provide mature and old-growth conditions a 200-year rotation would provide better long-term use by those species specialized to old-growth conditions.

- At least until research indicates differently, stand size should average about 84 acres (34 ha) (Thomas et al. 1979). Smaller average stand size is probably satisfactory for habitat stages 1 through 3C, as most species nesting in them have smaller territories and home ranges than some of the specialists in stages 4A, 4B, and 4C. Provision of smaller stands in early stages is compatible with provision of larger stands in later stages by appropriate spacing and timing of cut blocks. For example, with a 200-year rotation, four clustered 25-acre (10-ha) blocks of a 100-acre management unit could be cut 50 years apart in a manner that would provide smaller patches of early successional stages for a long period of time, while adjacent blocks late in the rotation would provide a 50-acre (20-ha) block of mature to old-growth habitat indefinitely. This represents 50 percent of the unit.

- Regional policy for snag management, as a minimal target, should be observed.

- A substantially greater number and variety of forest birds would utilize "clearcut" blocks if just a few trees and snags were left and if some slash were left, including some piles.

- Herbicide control of shrub competition with regeneration stands should be confined to the area immediately surrounding affected trees, to retain some shrub cover for birds and other wildlife.

- Dense stands of trees ranging from 20 to 50 feet (6.1 to 15.2 m) high (habitat stage 3C) should be thinned to encourage more rapid growth to large tree stages.

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BIRD COMMUNITIES IN MIXED CONIFER FORESTS OF THE INTERIOR NORTHWEST

H. Reed Sanderson
Range Scientist
Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, La Grande, Oregon

Evelyn L. Bull
Wildlife Biologist
Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, La Grande, Oregon

Paul J. Edgerton
Wildlife Biologist
Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, La Grande, Oregon

ABSTRACT

Forest management practices adjust the direction and pace of plant succession. The species composition and structure are altered, and, in turn, the avian species. Forest management must include wildlife as an integral part of the management decision. A wildlife biologist must provide sound biological alternatives for the land manager's consideration. We present a discussion of ecological concepts that wildlife biologists can use to predict the response of bird alterations in the interior Northwest mixed conifer forest type.

KEYWORDS: mixed conifer forest, silviculture, birds, nongame habitat.

Society's demand for products is the primary driving force for the management of our natural resources. Whatever that management is, it also affects wildlife populations whenever habitat is altered. As the human population increases in number and affluence, the demand for products will also increase (Maser 1979). Although timber harvest, livestock grazing, and wildlife harvest provide products, they also "...stir man's economic interest and, in the longer term, protective interest" (Maser and Thomas 1978:2). Economic demands must now be balanced by ecological consequences because of such laws as the Environmental

Policy Act, Federal Land Policy and Management Act, and the Forest Policy Act. Specifically, a land manager is to be held responsible for the consequences of his decisions and their resulting impact on the resource, land, and environment. A wildlife biologist's role is to provide a land manager with a set of management alternatives and their respective consequences to habitats and attendant wildlife species. The responsibility of wildlife biologists is to provide biologically sound data. We can no longer shirk our responsibility with the too often heard wildlife biologists' rationalization that, "We do not have enough information."

Our objective is to provide wildlife biologists with some ecological concepts to assist in predicting the generalized responses of both plant communities and birds to habitat alterations in the interior Northwest mixed conifer forests.

VEGETATION

The interior Northwest is characterized by a wide range of physical features that create a variety of habitats for different kinds of biotic communities. Diversity in these communities results not only from physiography, soils, and climate, but also from fire, insects, disease, and management activities such as timber harvesting and livestock grazing.

Foresters and ecologists have studied the vegetation of the mixed conifer forests that occupy about 10.5 million hectares of the interior Northwest. Kuchler (1964) broadly mapped this area as Douglas-fir (*Pseudotsuga menziesii*)[1/] in the northern Rocky Mountains and Washington, cedar-hemlock-pine (*Thuja-Tsuga-Pinus*) forests in the northern Rocky Mountains, and grand fir (*Abies grandis*) - Douglas-fir forests in central Idaho, eastern Oregon, and southeastern Washington. Regional ecologists have refined these forest descriptions to provide an ecologically based system of land stratification for use by local resource planners and land managers. They include Franklin and Dyrness (1973), Oregon and Washington; Hall (1973), the Blue Mountains of eastern Oregon and southeastern Washingon; Daubenmire and Daubenmire (1968), northern Idaho and adjacent Washington; Steele et al. (Being prepared), central Idaho; and Pfister et al. (1977) for Montana.

Interior Northwest coniferous forests occur along a predictable environmental gradient. Climax Douglas-fir associations are usually found at mid-elevations where they intergrade with the upper limits of more xeric ponderosa pine (*Pinus ponderosa*) forests. In some areas, such as north-central Washington and the east slopes of the northern Rocky Mountains, however, climax ponderosa pine may be absent and Douglas-fir forests may border grasslands or shrub-steppe vegetation. In Idaho and the Blue Mountains of Oregon and Washington, climax Douglas-fir forest is less common. Instead, it is an important component of mixed conifer communities transitional from ponderosa pine to grand fir. Douglas-fir and grand fir generally dominate climax stands, but Engelmann spruce (*Picea engelmannii*) may be locally abundant on moist sites, and subalpine fir (*Abies lasiocarpa*) becomes an important component at higher elevations.

Fire has played a major role in determining the composition and stucture of mixed conifer forests. Ponderosa pine, lodgepole pine (*Pinus contorta*), western white pine (*Pinus monticola*), or western larch (*Larix occidentalis*) dominate seral stands because they are better adapted to severe disturbance, especially fire, than are the climax species. Ponderosa pine or lodgepole pine

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1/ Nomenclature follows that of Garrison et al. (1976).

may persist on harsher sites as a fire climax. On the other hand, grand fir and Douglas-fir regenerate abundantly in either mature, undisturbed stands, or seral stands. In the latter situation, they gradually assume dominance as the stand develops.

Composition and structure of the associated understory vegetation is diverse and depends on interactions of site, plant community, fire, and forest management activities. On drier sites dominated by Douglas-fir or mixed Douglas-fir and ponderosa pine, grasses mixed with scattered low shrubs and forbs characterize the understory. Dense, multilayered understories of grasses, sedges, forbs, and tall shrubs occur on moist sites where Douglas-fir dominates the overstory. Some characteristic species are pinegrass (Calamagrostis rubescens), elk sedge (Carex geyeri), arnica (Arnica spp.), ninebark (Physocarpus malvaceus), and snowberry (Symphoricarpos albus). The understory of mature or old-growth mixed conifer forest dominated by grand fir is often characterized by low growing plants such as American twinflower (Linnaea borealis), queencup beadlily (Clintonia uniflora), and princespine (Chimaphila spp.). Wild rose (Rosa spp.), huckleberries (Vaccinium spp.), yew (Taxus sp.), and other shrubs are abundant in some communities.

Fire can be an important influence in understory development. Intense heat generated by either wildfire or prescribed burns can destroy understory vegetation and favor the germination and establishment of seral shrubs. Dense fields of shrubs, such as snowbrush ceanothus (Ceanothus velutinus) and ninebark may dominate disturbed Douglas-fir sites for 25 years or longer while the seral forest develops. On the other hand, periodic, light underburning once maintained open stands of Douglas-fir mixed with ponderosa pine (Hall 1977).

BIRDS OF THE MIXED CONIFER FOREST

More than 90 species of birds use the mixed conifer forests in the interior Northwest (Thomas 1979, Sundstrom 1978). None of these birds, however, restrict their feeding and reproductive activities to a single forest type or to a particular tree species. Because interior Northwest forests tend to be a mosaic of forest types instead of large continuous blocks, management objectives generally are not restricted to a particular forest type. Also, birds apparently respond more to vegetative structure than they do to plant species composition per se (Verner 1975). Consequently, management of bird communities should not be considered by forest type, but rather by the overall impact of management on forest structure.

Vegetative structure can be broadly equated to forest succession. As succession progresses, plant species diversity and biomass increase; vegetative structure becomes more complex, which in turn, creates more available niches that result in increased bird species diversity (Meslow 1978) (Fig. 1). We have characterized the mixed conifer forest type with six successional stages, and have listed the birds that feed or reproduce in each successional stage (Appendix 1).

Although we may not have all the specific information about habitat requirements for all birds, we can fairly well predict the impact of various management schemes on vegetative structure and plant succession and, consequently, on bird species. Forest managers may wish to maintain as many naturally occurring habitats as possible so future generations can have the same management options we have today (Balda 1976). "Wildlife Habitats in Managed Forests"

(Thomas 1979) and "A Holistic Approach to Wildlife and Fish Habitat Management" (Sundstrom 1978) are two publications that can be used to predict impacts of forest management decisions on birds.

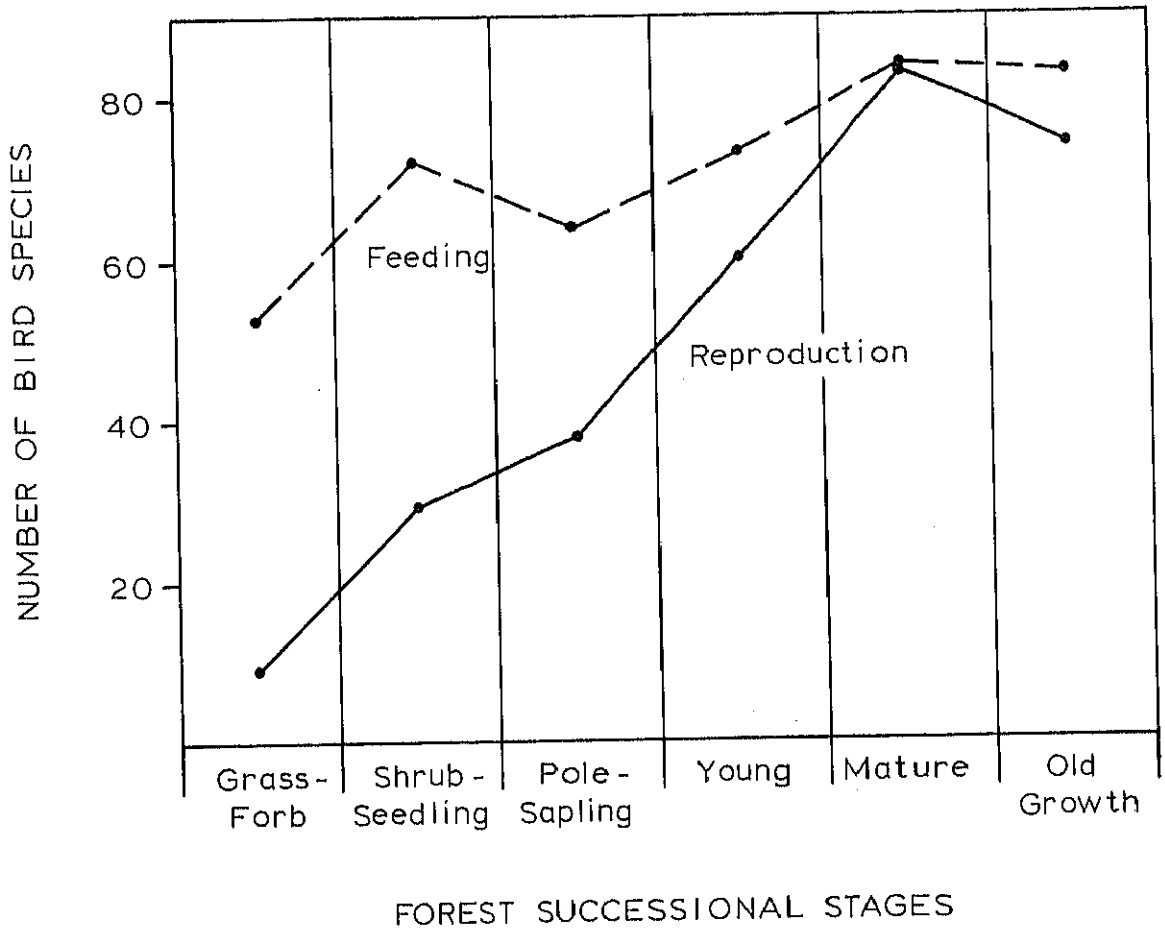

Figure 1.--Enumeration of bird species orientation to forest successional stages in the mixed conifer forest type of the interior Northwest.

FOREST MANAGEMENT

Forest management is the dominant land management activity in the interior Northwest forests. Forest management is bird habitat management and can achieve habitat management goals with attentive planning and execution (Thomas 1979).

A forest manager is limited in the selection of silvicultural options because of stand conditions due to past logging practices, insect and disease problems, control of fire, and so on. Therefore the selection of a silvicultural system

must be made on a stand by stand basis. Generally healthy, mixed-aged stands are suitable for uneven-aged management, but care must be taken to prevent a shift in species composition, especially in the mixed conifer forests of eastern Oregon and Washington. But, an even-age management system is usually recommended to control dwarf mistletoe (Arceuthobium spp.) and western spruce budworm (Choristoneura occidentalis Freeman), that are prevalent throughout the area (Seidel 1973, Wellner and Ryker 1973). Open stands favor larch and pine, and closed stands favor the shade tolerant firs. Douglas-fir is a shade requiring species in the interior Northwest, and seedling establishment is best in partial shade, but growth is best in full sunlight (Seidel 1973). Because each silvicultural system has a specific impact on habitats, wildlife biologists must have a basic understanding of these systems to predict the consequences of their application.

There are four generalized forest management systems that adjust the direction and pace of plant succession and, in turn, determine the avian species associated with the various successsional stages.

1. Even-aged management produces a monoculture of trees approximately the same size and height. A stand has an identified establishment period, and the entire stand is generally removed at maturity (Franklin and DeBell 1973, USDA Forest Service 1973).

   Even-aged management reduces vertical vegetative complexity and results in a decrease in bird species diversity (MacArthur and MacArthur 1961).

   Horizontal vegetative complexity (spacing) is increased by creating different successional stages between the various stands or cutting units. Edges are also created where different successional stages meet, thereby enhancing bird species richness (Thomas et al. 1978).

   All guilds (a group of species that use the habitat in a similar way; Root 1967) could be represented through several even-aged stands, but this depends on the successional stages present within a particular time.

2. In contrast, uneven-aged management develops vertical vegetative complexity, but eliminates horizontal complexity by harvesting only mature trees, by not cutting the entire stand, and by maintaining trees in a variety of size classes (Franklin 1977, Hann and Bare 1979).

   Edges and early successional stages are minimized, as well as, the characteristics of old-growth stands. Bird species characteristic of the related plant communities would also be reduced. For example, aerial-searchers and ground-brush foragers would decrease, while bark and foliage gleaners and drillers would increase.

3. Intensive forest management shortens early successional stages and eliminates the final stages by emphasizing stand regeneration, growth, and harvest (Edgerton and Thomas 1978). Silviculture practices may include brush control, tree planting, fertilization, and thinning--all of which tend to accelerate tree establishment and growth and reduce plant species diversity and structural complexity.

Intensive forest management potentially decreases bird species diversity. Succession is accelerated; maturity is brief.

Harvest of climax old-growth stands eliminates the associated specialized bird species, such as the brown creeper (Certhia familiaris), pileated woodpecker (Dryocopus pileatus), and great gray owl (Strix nebulosa).

4. Salvage and sanitation logging and debris disposal activities remove snag recruits and snags and reduce the amount of dead and downed woody material that provides feeding and nesting sites for drilling and bark-gleaning guilds (Maser et al. 1979, Thomas et al. 1979). Snags also are needed for nest sites for a wide variety of birds. In addition, snags and broken-topped trees are needed for nesting and perching sites for such large birds as eagles (Aquila and Haliaeetus spp.) and osprey (Pandion haliaetus).

The main management tool available to a wildlife biologist is to direct the size, shape, location, and timing of silviculture practices.

Size of a treatment area has a direct relationship to the number of species present (Galli et al. 1976). Thomas et al. (1978) estimated that bird species richness is optimized at about 34 ha in the Blue Mountains. Such area figures must be applied with caution, however, because they tend to become policy. Verner (1975) suggested that a better approach would be to use the territory size of large raptors, such as hawks and owls, because they could also serve as indicators of the bird population vitality.

The shape of an area is related to the amount of edge produced--the more irregular the shape, the greater the edge. Irregular shapes are also more pleasing to a viewer and provide a more natural condition.

Location of a treatment area refers to its relationship to other forest communities. Edges differ in their degree of contrast. For example, a sapling stage against pole stage has a low degree of contrast, whereas a grass stage against a mature forest stage has a high degree of contrast. Considering six generalized successional stages, there is a possible combination of 15 edges, all with a varying degree of contrast (Thomas et al. 1978). The juxtaposition of various treatments can be used to achieve habitat diversity.

The final variable is time--time in relation to season of the year, and time in relation to rotation age or number of years from tree establishment to cutting. For example, timing of a prescribed burn may be critical to ground and shrub nesting birds if it is done in the spring of the year, but the distribution of silvicultural practices over years and ages of a stand affects both the pace and direction of succession.

In summary, we paraphrase a portion of The Wildlife Society's position statement on "Wildlife Needs in Forest Management" as adopted on March 24, 1979:

> Forest management practices alter species composition and structure of plant communities and thereby affect attendant wildlife. Wildlife species may increase, or decline, or be unaffected. Species with a narrow range of tolerance for habitat change may require special consideration.

Forest and wildlife management objectives can be coordinated by maintaining diversity of plant species, age classes, and stand densities; by retaining snags and dead and down woody materials; and by varying the size, shape, age, and juxtaposition of stands. Management plans must be flexible but also must be specific enough to meet local conditions. Management practices must be prescribed according to site conditions, plant and animal species involved, successional relationships, and such local factors that ensure a diversity of wildlife species.

Wildlife should be an intentional product of forest management. It is a wildlife biologist's responsibility to provide a manager with a set of alternatives. It is a land manager's responsibility to review the consequences of these alternatives and the trade-offs on wildlife and their habitats (The Wildlife Society 1979).

We submit that this is our professional charge.

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Appendix 1.--Bird species feeding (F) or reproducing (R) in the mixed conifer forest successional stages of the interior Northwest

Species	Forest Successional Stage					
	Grass-forb	Shrub-seeding	Pole-sapling	Young	Mature	Old-growth
Wood duck[1/] *Aix sponsa*	F	F	F	F	R F	R F
Barrow's goldeneye *Bucephala islandica*	F	F	F	F	R F	R F
Bufflehead *Bucephala albeola*	F	F	F	F	R F	R F
Harlequin duck *Histrionicus histrionicus*	F	F	F	R F	R F	R F
Hooded merganser *Lophodytes cucullatus*	F	F	F	F	R F	R F
Turkey vulture *Cathartes aura*	R F	R F				R F
Goshawk *Accipiter gentilis*		F		F	R F	R F
Sharp-shinned hawk *Accipiter striatus*		F	R F	R F	R F	F
Cooper's hawk *Accipiter cooperii*	F	F	F	R F	R F	F
Red-tailed hawk *Buteo jamaicensis*	F	F	F	R F	R F	R F
Golden eagle *Aquila chrysaetos*	F	F	F	F	R F	R F
Bald eagle *Haliaeetus leucocephalus*	F	F			R F	R F
Osprey *Pandion haliaetus*	F	F	F	F	R F	R F

[1/] Nomenclature follows that of American Ornithologists' Union (1957, 1973a, 1973b, 1976).

Appendix 1.--Continued.

Species	Forest Successional Stage					
	Grass-forb	Shrub-seeding	Pole-sapling	Young	Mature	Old-growth
Peregrine falcon *Falco peregrinus*	R F	R F	R F	R F	R F	R F
Merlin *Falco columbarius*	F	F	F	F	R F	R F
American kestrel *Falco sparverius*	F	F		R	R	R F
Blue grouse *Dendragapus obscurus*	F	R F	R F	F	F	F
Franklin's grouse *Canachites canadensis*		F	R F	R F	R F	F
Ruffed grouse *Bonasa umbellus*		R F	R	F	R F	R F
Turkey *Meleagris gallopavo*	F	R F	R	R	F	F
Barn owl *Tyto alba*	F	F			R F	R F
Flammulated owl *Otus flammeolus*	F	F		R	R F	R F
Great horned owl *Bubo virginianus*	F	F	F	R F	R F	R F
Pygmy owl *Glaucidium gnoma*	F	F	F	R F	R F	R F
Barred owl *Strix varia*	F	F			R F	R F
Great gray owl *Strix nebulosa*	F			R F	F	F
Long-eared owl *Asio otus*	F	F	F	R F	R F	R F
Saw-whet owl *Aegolius acadicus*				R	R F	R F
Vaux's swift *Chaetura vauxi*					R F	R F
Black-chinned hummingbird *Archilochus alexandri*	F	R F	R F	F	F	F
Rufous hummingbird *Selasphorus rufus*	F	R F	R	R	R F	R
Calliope hummingbird *Stellula calliope*	F	R F	R F	F	F	F
Belted kingfisher *Megaceryle alcyon*	R F	F	F	F	F	F
Common flicker *Colaptes auratus*	F	F	F	R F	R F	R F
Pileated woodpecker *Dryocopus pileatus*					R F	R F
Lewis' woodpecker *Melanerpes lewis*	R	R		R F	R F	R F

Appendix 1.--Continued.

Species	Forest Successional Stage					
	Grass-forb	Shrub-seeding	Pole-sapling	Young	Mature	Old-growth
Williamson's sapsucker *Sphyrapicus thyroideus*					R F	R F
Hairy woodpecker *Picoides villosus*				R F	R F	R F
White-headed woodpecker *Picoides albolarvatus*					R F	R F
Black-backed three-toed woodpecker *Picoides arcticus*				R F	R F	R F
Alder flycatcher *Empidonax alnorum*		F	R F	R F		
Willow flycatcher *Empidonax traillii*		F	R F	R F		
Hammond's flycatcher *Empidonax hammondii*		F	F	F	R F	R F
Dusky flycatcher *Empidonax oberholseri*	F	R F	R F	R F	R F	R F
Western flycatcher *Empidonax difficilis*		F	F	R F	R F	R F
Western wood pewee *Contopus sordidulus*		F	F	R F	R F	R F
Olive-sided flycatcher *Nuttalornis borealis*	F	F	R F	R F	R F	R F
Tree swallow *Iridoprocne bicolor*	F	F		R	R	R F
Gray jay *Perisoreus canadensis*		F	R F	R F	R F	F
Steller's jay *Cyanocitta stelleri*	F	F	R F	R F	R F	R F
Black-billed magpie *Pica pica*	F	R F	R F	R F	R F	R F
Common raven *Corvus corax*	R F	R F				R F
Common crow *Corvus brachyrhynchos*	F	F	F	R F	R F	R F
Clark's nutcracker *Nucifraga columbiana*				F	R F	R F
Mountain chickadee *Parus gambeli*			R F	R F	R F	R F
Chestnut-backed chickadee *Parus rufescens*			R F	R F	R F	R F
White-breasted nuthatch *Sitta carolinensis*					R F	R F
Red-breasted nuthatch *Sitta canadensis*				R F	R F	R F

Appendix 1.--Continued.

Species	Forest Successional Stage					
	Grass-forb	Shrub-seeding	Pole-sapling	Young	Mature	Old-growth
Pygmy nuthatch *Sitta pygmaea*					R F	R F
Brown creeper *Certhia familiaris*				F	R F	R F
Dipper *Cinclus mexicanus*	R F	R F	R F	R F	R F	R F
House wren *Troglodytes aedon*	F	F	R F	R	R	R
Winter wren *Troglodytes troglodytes*		R F	R F	F	R F	R F
Rock wren *Salpinoles obsoletus*	R F	R F				
American robin *Turdus migratorius*	F	R F	R F	R F	R F	R F
Varied thrush *Ixoreus naevius*		F	R F	R F	R F	R F
Hermit thrush *Catharus guttatus*			F	F	R F	R F
Swainson's thrush *Catharus ustulatus*		R F	R F	R F	R F	R F
Western bluebird *Sialia mexicana*	F	F		R	R	R
Mountain bluebird *Sialia currucoides*	F	F		R	R	R
Golden-crowned kinglet *Regulus satrapa*		F	F	R F	R F	R F
Ruby-crowned kinglet *Regulus calendula*			F	F	R F	R F
Solitary vireo *Vireo solitarius*			R F	R F	R F	R F
Nashville warbler *Vermivora ruficapilla*		R F	F	F		
Yellow-rumped warbler *Dendroica coronata*			F	R F	R F	R F
Black-throated gray warbler *Dendroica nigrescens*		R F	R F	R F	R F	R F
Townsend's warbler *Dendroica townsendi*				F	R F	R F
MacGillivray's warbler *Oporornis tolmiei*		R F	R F	R F	R F	
Wilson's warbler *Wilsonia pusilla*		R F	R F	R F	R F	
Northern waterthrush *Seiurus noveboracensis*	R F	R F				
Yellow-breasted chat *Icteria virens*		R F	R F	R F	R F	F

Appendix 1.--Continued.

Species	Forest Successional Stage					
	Grass-forb	Shrub-seeding	Pole-sapling	Young	Mature	Old-growth
Northern oriole *Icterus galbula*		R F	R F	R F	R F	
Brewer's blackbird *Euphagus cyanocephalus*	F	R F	R F	R F	R F	R F
Brown-headed cowbird *Molothrus ater*	R F	R F	R F	R F	R F	F
Western tanager *Piranga ludoviciana*		F	F	R F	R F	R F
Black-headed grosbeak *Pheucticus melanocephalus*	F		F	R F	R F	R F
Evening grosbeak *Hesperiphona vespertina*	F		F	F	R F	R F
Purple finch *Carpodacus purpureus*	F	F	R F	R F	R F	R F
Cassin's finch *Carpodacus cassinii*	F	F	F	R F	R F	R F
House finch *Carpodacus mexicanus*	F	R F	R F	R F	R F	F
Pine grosbeak *Pinicola enucleator*			F	F	R F	R F
Pine siskin *Carduelis pinus*	F	F	R F	R F	R F	R F
Red crossbill *Loxia curvirostra*				F	R F	R F
Dark-eyed junco *Junco hyemalis*	R F	R F	R F	R F	R F	R F
Chipping sparrow *Spizella passerina*	F	R F	R F	R F	R F	R F
Song sparrow *Melospiza melodia*		R F	R F	R F	R F	

MANAGEMENT OF LODGEPOLE PINE FOR BIRDS

Dale Hein

Professor of Wildlife Biology
Department of Fishery and Wildlife Biology
Colorado State University
Fort Collins, Colorado 80523

ABSTRACT

Communities of birds in lodgepole pine (Pinus contorta) are among the least studied of all major forest types. Research must get top priority before specific management is feasible. Goals have not been critically examined for birds in lodgepole pine (LPP). Only a few of the many parameters of bird communities in LPP have been recognized. Management practices which increase or maintain interspersion and variety of habitats in LPP associes should enhance characteristics of avifauna generally considered desirable in management of nongame birds. These include species richness, species diversity, abundance, and visibility of birds. No species of bird is dependent exclusively on LPP, and this forest type is unlikely to be greatly reduced in area in the near future. Judged by prevailing values of humans, bird communities will usually benefit from more intensive and extensive management of LPP forests. General guidelines for current management are discussed, and recommendations for improving future management of LPP for birds are presented.

KEYWORDS: lodgepole pine, birds, nongame, habitat, wildlife

LODGEPOLE PINE

Lodgepole pine (LPP) dominates nearly 6 million hectares in the United States and over three times as much area in western Canada. In area, LPP is the third most important, and in ecologic amplitude, one of the most ubiquitous forest types in the western United States (Wellner 1975).

LPP is a pioneer species, sometimes in mixed stands with other conifers, but often occurring, as in the upper montane zone of the central Rocky Mountains, in vast forests of pure LPP that resulted from catastrophic fires. LPP may sometimes be a fire subclimax, and in a few places may represent an edaphic-topographic climax.

In the central Rocky Mountains, pole timber is the primary stocking class of LPP forests, often with little potential for saw timber because of over-mature trees, overly dense stands, and poor sites (Alexander 1974). Only 5 to 6 percent of the stands are seedlings and saplings. LPP often forms a dense, single-story canopy with virtually no understory and sparse lower strata. Ecology and characteristics of LPP were described in a number of papers included in Baumgartner (1975), especially Pfister and Daubenmire (1975).

MANAGEMENT OF LODGEPOLE PINE

Lodgepole pine (LPP) was virtually unmanaged and unharvested until the 1950's (Bernsten 1975). During the 1960's, clearcutting of LPP increased and so did public concern for environmental impacts of timber management. This stimulated research for management of LPP. A benchmark was reached in October 1973 with a symposium, Management of Lodgepole Pine Ecosystems (Baumgartner 1975).

Management of LPP has focused on cutting practices, regeneration, disease and insect control, and occasionally on thinning. Recent research in fire management in LPP has scarcely been applied on a significant scale. Tackle (1954) recognized early that clearcutting was the most practical method of harvesting LPP forests. Lotan and Alexander (1973) stated that the choices were usually clearcut or uncut LPP because of problems of windthrow, spread of dwarf mistletoe, and slash management in various partial cutting alternatives. However, exceptions for partial cutting of LPP occur occasionally (Alexander 1972). Clearcuts can be patch, block, or strip, and there are no advantages to clearcuts larger than 16 hectares (Alexander 1974). Recommended stocking densities for multiple use management featuring timber production are above 1500 seedlings or saplings per hectare (Alexander 1974). Optimum stocking levels for timber production can be calculated from average tree diameter and basal area on the site (Adams 1969), e.g., from 600 to 1000 per hectare for trees 20 centimeters in diameter. Insects and disease are sometimes controlled in LPP by sanitation and salvage clearcutting tailored to specific situations. Precommercial thinning at about 20 years of age and commercial thinning of LPP can be successful cultural practices but are seldom done (Cole 1975).

BIRDS IN LODGEPOLE

There have been few extensive studies of avifauna in lodgepole pine (LPP) communities; data are especially scarce for non-nesting seasons. Snyder (1950) and Salt (1957) provided the most detailed studies of birds in LPP. Wiens (1975) reviewed avian communities in coniferous forests using a data base of 130 censuses of breeding birds in the literature. Wiens (1978) used 29 of those censuses in a review of non-game birds in Pacific Northwest coniferous forests. From those useful reviews, I extracted data from eight studies which reported bird censuses in lodgepole forests; most were from mixed forest types and mainly from the central Rocky Mountains. Data from Roppe and Hein (1978) and unpublished data (on file with the author at Colorado State University, Fort Collins) were also used for the following discussion. Apparently, there are no other published studies of bird communities in LPP.

The most abundant species nesting in lodgepole habitat in Colorado (Roppe and Hein 1978) include Yellow-rumped (Audubon's) Warbler, Ruby-crowned Kinglet, Gray-headed Junco, Hermit Thrush, Black-capped and Mountain Chickadees, Pine Siskin, Gray Jay, and Townsend's Solitaire (standard common names currently in use by American Ornithologists' Union). "Parus-Spinus" (Chickadee-Siskin) was a proposed name for this avian community (Snyder 1950). No species of bird is restricted to LPP.

Birds in lodgepole habitat often occupy diverse, broad niches. The few species which use lodgepole for food rank low in abundance among species in this habitat. Blue grouse is the only important game bird and the only species feeding significantly

on LPP foliage in most lodgepole communities. Clark's Nutcracker and Pine Grosbeak eat lodgepole seeds and are more closely associated with LPP than are other birds; however, they are low in abundance in the community and are more common in types dominated by spruces and true firs. The most abundant guild of birds in LPP is comprised of species which feed on insects on live foliage and bark. This guild includes kinglets, warblers, chickadees, and nuthatches. Niches of these species may be more finely divided and specialized than are niches of birds in other guilds which use different parts of LPP habitat (Sabo and Whittaker 1979).

Communities of birds nesting in LPP forests exhibit highly variable and intermediate densities (150-900 per square kilometer) and standing crop biomass (25-200 grams per hectare) (Wiens 1975). Number of species is typically low (8-20) as is species diversity. Roppe and Hein (1978) calculated a value of 3.0 for Shannon-Wiener index of species diversity of breeding birds in LPP in Colorado. Species dominance is high, with one species often accounting for one-fourth of all birds, and the two most-abundant species including half of all birds.

Diversity of vegetation in LPP communities appears to affect several parameters of the associated avifauna. Comparing four studies in LPP with five studies in LPP-mixed conifer communities, species richness, density and biomass were higher in the mixed communities, but species dominance was greater in the avifauna of the pure LPP (Table 1).

Table 1.--Comparison of parameters of bird communities in lodgepole pine and lodgepole pine-mixed coniferous forests; data are from Wiens (1975) and Roppe and Hein (1978), mainly from Rocky Mountains.

Communities and number of studies	Statistic	Number of species	Density (birds/km^2)	Standing crop biomass (g/ha)	Dominance (2 species)
Lodgepole pine (4)	Range:	8-14	146-322	25-73	41-65%
	Mean:	11	238	54	53%
Lodgepole pine-mixed conifer (5)	Range:	10-20	493-905	126-204	26-46%
	Mean:	14.4	713	149	33%

Effects of habitat disturbance on birds of LPP have seldom been studied. Roppe and Hein (1978) used standard techniques of spot-mapping territories to compare bird populations on a 8-year-old burn, ecotone, and unburned lodgepole forest in north-central Colorado. Breeding densities of birds per 100 hectares were 108 pairs in the burn, 110 pairs in the ecotone and 73 pairs in lodgepole. Standing crop biomass and consuming biomass were higher on the burn, but efficiency of food utilization by avifauna was higher in unburned lodgepole. The ecotone between the LPP and burn had more individuals and more species of birds than did either of the other habitats. There were 14 species in LPP, 13 in the burn, and 18 in the ecotone. The Shannon-Wiener index of species diversity was 3.3 for the burn and 3.0 for the LPP. Abundant species, such as Blue Grouse and Clark's Nutcracker, occurred on both sites. American Robin, Mountain Bluebird, Broad-tailed Hummingbird, Common Flicker, and Empidonax flycatchers, occurred mainly on the burn in place of Hermit Thrush, Ruby-crowned Kinglet, and chickadees in LPP. Thus, the greatest differences between the two communities of birds were in species composition and relative abundance of some of the most common

species. Because most birds in LPP forests are euryoecious, noticeable changes in relative abundance can be expected to occur at lower levels of habitat change than is required to affect species composition.

Apparently, no substantial studies have been published on bird populations in LPP in nonbreeding seasons. Unpublished data on file with the author at Colorado State University, were collected by Alan Dale to compare birds on a clearcut and adjacent mature LPP forest in Larimer County, Colorado, in late winter. The data are from area transect counts replicated five times on two 10-hectare plots, one in each community. Although the data are meager (Table 2), species richness, species diversity and abundance were higher in LPP than in the clearcut in winter. Mountain Chickadee was the only one of eight species recorded in both habitats.

Table 2.--Comparison of late-winter birds during five area transect counts on two 10-hectare plots, one in a clearcut and one in adjacent mature lodgepole pine forest, Larimer County, Colorado, March-April 1977.

	Clearcut		Lodgepole	
	Maximum number	Frequency	Maximum number	Frequency
Goshawk			1	60%
Hairy Woodpecker			2	40%
Gray Jay			2	60%
Mountain Chickadee	2	60%	7	80%
American Robin			1	40%
Bohemian Waxwing	8	20%		
Pine Grosbeak			4	20%
Gray-headed Junco	4	60%		

MANAGEMENT OF LODGEPOLE FOR BIRDS

Perspectives and Discussion

The paucity of information concerning effects on wildlife of manipulation of lodgepole pine (LPP) is surprising. A few studies on responses of big game to management of LPP were reviewed by Dealy (1975), and there were a few reports of small mammal populations and LPP management, usually from the viewpoint of damage to LPP by mammals, e.g., Lindsey (1975). The only mention of birds in the 37 papers in the 1973 symposium on LPP management (Baumgartner 1975) was to allude to their "damaging" (which could be called "utilizing") of LPP (Lindsey 1975).

Foresters have attempted to develop management prescriptions for LPP in which effects on wildlife are considered. For example, one national forest in Colorado, in developing its timber management plan in 1977, predicted the impact on wildlife of up to four alternative treatments on six stand combinations of LPP. From a base index value of 100 for no effects of no treatment, the index was projected only as high as 114 for thinnings followed by patch clearcuts and only as low as 94 for light shelterwood cuts in sawtimber on poor sites. These were subjective predictions for numbers and distributions of five combined categories of wildlife — big game, small game, nongame, fishes, and reptiles. Clearly, little can be inferred about forest management for nongame birds when such a broad, subjective approach is used, even by competent

forest-wildlife biologists. Negligible effects are almost certain on a combined wildlife index from almost any timber management; adverse and beneficial effects on different species often cancel each other out in the index, giving a misleading indication of no effect. Forest managers are not to blame for using a crude method when nothing better is available.

We are not ready to manage LPP for nongame birds. The data base is inadequate and goals are not established. Fortunately, we don't face critical situations for nongame birds in LPP. There are no birds restricted to LPP, no endangered species that depend primarily on LPP for habitat, and little likelihood that much of the vast area of LPP forest will be significantly altered in the 1980's. We have an unusual opportunity to "do it right" in LPP.

First, we should describe the avifauna of LPP communities--not just annotated lists, but quantification of parameters of bird communities including species composition, relative and absolute abundance, standing crop and consuming biomass, energy flow, trophic structure, species diversity, dominance, association, interdependence, periodicity, and productivity. Many parameters can be estimated from simple list-count data, if surveys are designed properly. More complex studies and models are needed to estimate characteristics such as productivity, resiliency, and energy flow. Detailed ecologic investigations of species are also needed to describe niches, define guilds, and identify key species for featured species management.

Second, we should document effects of LPP manipulation and succession on bird communities. Most effective and practical would be a series of well-designed surveys at all seasons before and after manipulation of LPP. Often, these studies could be adapted to concurrent timber management activities. Similar site comparisons (Roppe and Hein 1978) can also be used for faster but less precise assessment of effects of habitat change. Studies of bird population changes after forest changes in other community types (Bock and Lynch 1970, Franzreb 1977, Hagar 1960, and Kilgore 1971) provide only useful starting points for designing the needed research.

Third, we need goals for management of nongame birds in LPP. A lack of defined goals and objectives is a general problem for wildlife management in western forests (Miller 1978). Do we have even tentative goals? Traditional emphasis of game managers on numbers has undoubtedly pervaded our thinking about nongame birds. Recently, there have been some healthy reservations about maximizing diversity. Odum (1969) described three components of diversity--variety, stratification and evenness--and how these differ from species richness. From the preservationists, we have probably accepted an overemphasis on making stability of bird communities a goal. We need a broad perspective to think in terms of spatial and temporal mixes of successional stages of LPP. For birds in LPP, regular and mild perturbation of habitat for "pulse stability" appears to be a less desirable alternative to creating a mosaic of successional stages over large areas by

A practical approach to management of forest habitat for wildlife was described by Thomas et al. (1976), who argued that management decisions are being made now and that wildlife biologists must do their best now to predict effects of habitat changes on wildlife. Briefly, all species of vertebrates in an area were grouped into "life forms" based on required reproduction sites and feeding habitat. Wildlife information was organized on four levels from gross responses of life forms to habitat changes to available biological information and literature references for individual species. Effects on wildlife, primarily changes in abundance of life forms, could then be predicted for changes in timber types, successional stages and temporal and spatial arrangements of stands. This approach is being applied now in better-studied forest communities and may be useful for nongame birds in LPP in the future. However, I contend that ecology of nongame birds is too poorly known to apply this approach with confidence in LPP at this time. Also, abundance of species or groups may be over-emphasized as a community parameter. I also favor more emphasis on traditional basis of grouping species into guilds according to ecologic function, instead of into life forms based on a few habitat uses. The approach of Thomas et al. (1976) is due for a detailed presentation in a book to be published soon.

Some Guidelines

Management options for lodgepole pine (LPP) usually reduce density of the canopy to varied degrees by various cutting practices or by burning. Thinning which retains uniformity of spacing has less influence on birds in LPP than does thinning based on a diameter limit, which results in a mosaic of habitat types similar to results of some fires that enhance many desirable features of bird communities. Optimum thinning densities are probably slightly lower for birds than for timber production. Research in progress and general observations indicate that thinning by diameter limit to fewer than 750 trees per hectare may be recommended where birds have top priority. This will permit ground cover to develop and facilitate stratification in the stand. Thinning old stands that won't respond to release cutting is still beneficial for wildlife. Blowdown in thinned stands can also benefit birds such as wrens that forage in dense, low cover.

Fire suppression in this century, and to a lesser degree control of insects and dwarf mistletoe, has resulted in an unnatural preponderance of dense, stagnant stands of LPP--the "doghair," monotonous forests that challenge managers. Unnaturally high accumulations of fuel have made difficult a return to natural fire policy, and research on prescribed burning in LPP has not yet led to extensive application of fire. If "naturalness" is a goal for bird communities in LPP, then a general guideline is that fire will help restore natural bird communities in our LPP forests. Fire should be a welcome, natural phenomenon in most LPP communities, and not just small, cool fires, but the full gamut of fires with which birds of LPP ecosystems evolved.

Conclusions of Dealy (1973) on management of LPP ecosystems for range and wildlife supported several important guidelines for cutting LPP that would be compatible with current traditional values of abundance and species richness of birds as well as beneficial for management of ungulates. Block or patch clearcuts should not exceed 16 hectares. Alternate-strip clearcuts should not exceed 60 meters in width with equal leave strips. Leave patches and irregular margins are desirable to increase edge and habitat diversity (Thomas et al. 1978).

Value and practicality of leaving snags during cutting of LPP is uncertain. Few suitable snags may exist in many even-aged stands, and isolated lodgepole pines are seldom windfirm. Bull (1978) showed that 40 to 180 snags per 40 hectares were needed for maximum population density of four species of woodpeckers characteristically inhabiting LPP forests in the Pacific Northwest. It was assumed that requirements of secondary cavity nesters would simultaneously be met if needs of excavators

(woodpeckers) for snags were satisfied. Leaving an average of five snags per hectare is a tentative guideline that needs to be evaluated with appropriate research.

Special consideration should be given to raptors in LPP forests. Carnivores integrate information about lower trophic levels. Top carnivores represent disproportionately high investments of energy and information from the community, and they may have important regulatory roles. Requirements of raptors in LPP are little known. Shuster (1976) found one Goshawk nest per 1640 hectares in 81 square kilometers of mainly LPP habitat in Colorado. All nests were within 2 kilometers of main roads, but whether or not special protection was needed was unclear. Disruptive activity, such as cutting or burning, should be banned in any unusual case where a LPP stand is inhabited by a rare, endangered, or unique bird, such as an Osprey, Peregrine Falcon, or Goshawk.

RECOMMENDATIONS

(1) More research should be initiated on avifauna of lodgepole pine (LPP) and on the responses of bird communities to various habitat changes in LPP. Specific hypotheses should be tested with before-and-after surveys at all seasons on replicated pairs of treated and control plots.

(2) Goals must be established for management of birds in LPP. Meaningful public involvement should occur in determining these goals for individual units, such as each national forest or ranger district. Many characteristics of bird communities should be considered, not just abundance and number of species.

(3) Management prescriptions should be implemented with stated objectives on at least 1 to 2 percent of LPP on each national forest each year.

(4) Management of LPP should be evaluated in relation to objectives for birds, and results should be published.

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BIRDS IN ASPEN

Barbara L. Winternitz

Assistant Professor
The Colorado College
Colorado Springs, Colorado

ABSTRACT

The bird populations of three Colorado montane aspen (Populus tremuloides) stands are compared in an attempt to determine what factors are responsible for the high bird density and diversity found in aspen. The ecological factors considered in this study are:

1. the effect of surface water, soil moisture, and slope,

2. the effect of the vegetation, including the aspen, the understory vegetation, and the "edge effect" in aspen stands,

3. other biotic effects, including insect levels in the aspen understory, aspen fungal disease, and variation in the feeding habits of the birds.

The results of this study indicate that the insect fauna of aspen stands, and fungal infection of the trees, are the controlling agents governing bird density and diversity.

KEYWORDS: aspen, montane, bird species density, bird species diversity, aspen understory, insects, Fomes, edge effect.

Studies of montane bird populations have demonstrated that aspen forests (Populus tremuloides) are rich in both the number of bird species found there, and the number of individuals within each species. The deciduous aspen, and its relatively short life span clearly distinguish it from the surrounding conifers of the montane forest. These two characteristics, and several other differences, have been advanced to account for the great use of this forest type by a variety of birds. For convenience of discussion, I will separate these possible explanations into three categories:

1. Topographic conditions favoring aspen growth, including surface water, ground moisture, and slope exposure.

2. Vegetation effects, such as its deciduous nature, its foliage characteristics, the resultant shaded floor and understory, and the "edge effect".

3. Other biotic effects, including insect numbers living in the aspen understory, incidence of a certain fungal disease in aspen trees, and the feeding habits of the birds themselves.

Ever since I first noted what appeared to be the birds' decided preference for aspen, I have been trying to test these several hypotheses, and to discover which among them may be primary in determining bird density and diversity.

STUDY AREAS AND METHODS

Three areas of Colorado montane forest have been studied in the following ways:

1. Crow Gulch, on Pikes Peak near Colorado Springs, elevation 2658 to 2762 meters. A 20 hectare study grid of balanced montane vegetation including Pseudotsuga menziesii, Pinus ponderosa, Picea spps., Pinus flexilis, and meadow grasses, as well as aspen stands. Bird species were censused for five breeding seasons and several winters with the spot-map method. Insects found in the aspen forest floor vegetation and meadow areas were collected by sweep-nets during three summers, and analyzed. Aspen stands were inspected for the incidence of bird drillings and heartrot fungus, Fomes igniarius, sometimes called Phellinus tremulae. Stands are changing in response to reduced use by elk or Wapiti (Cervus canadensis).

2. Black Mountain, near Fairplay, Colorado, elevation 2926-3048 meters. A 24 hectare study grid of nearly pure aspen. Stands composed of all age groups indicate climax aspen, and have remained the same in known Colorado history. Study of the breeding bird populations by spot-map methods is now in its third year. Since no open water occurs there, and all slopes face west, the topographic conditions are somewhat controlled. There are definite edge effects between the aspen stands and the surrounding meadow. Bird drilling and Fomes infection of the trees has been intensively studied in one hectare. There is a large elk population, and some cattle use in the past.

3. South Mueller Ranch, west of Pikes Peak near Divide, Colorado, elevation 2530-2865 meters. A study area of 2,400 hectares of balanced montane vegetation is being inventoried for The Nature Conservancy. Almost 50% of the area is dominated by aspen vegetation. There are large stands of both "wet" and "dry" aspen where the relative influences of ground moisture can be investigated. Study is in its second year. The size of the area and its topography necessitated a difference in methods used. A combination of grid and transect bird census by six inventory workers was employed. There is a large elk population, and there has been some cattle grazing in the past.

RESULTS AND DISCUSSION

Bird Preference for Aspen

It was found at Crow Gulch that many montane breeding birds prefer aspen vegetation, and both the density and diversity of birds are greater there than in the coniferous stands. It was also shown that the birds in aspen exhibited a spread of breeding activity throughout the late spring and summer months that reflected a partitioning of food resources and feeding methods (Winternitz 1973 and 1976). Why? To answer this question, study was begun in the Black Mountain area, and then on the Mueller Ranch.

While breeding bird studies at such elevations begin in early May and end in August, the monitoring of winter bird populations shows some interesting facts. During the fall and winter months, from October to February, you find a lot of birds, or you find none. The wintering species tend to travel together, and are found in sheltered spots, or ones of good food resource. Raptors are scarce, and most bird activity occurs in coniferous areas, not in aspen. Both density and diversity of birds are low in winter, unless you happen to be in the middle of a mixed feeding flock.

Preliminary results of comparison of breeding bird species richness and densities for the three areas are shown in Table 1. Since the areas differ in length of study and method of study, a comparison of results within one area is more reliable than comparison between areas. Crow Gulch and Black Mountain have been studied longer, and with similar methods. The South Mueller Ranch study is both newer and used new methods; but the figures presented here are very conservative.

Table 1. Aspen breeding bird densities and diversity for three study areas.

Area	Total species per year	Species Number		Bird Density pairs/ha.
Crow Gulch (CG)	50 with 33/year (yr.)	16		10.0
Black Mountain (BM)	32/yr.			
low elevation		24		6.0
high elevation		14		3.7
South Mueller Ranch (SMR)	100			
	37 in aspen	10	Wet site	7.5
		5	Dry site	3.0

Reasons for Bird Use of Aspen

TOPOGRAPHIC CONDITIONS

Aspen vegetation is strongly tied to moisture, though it is not limited to wet areas (Marr 1967). Hoff (1957) discussed aspen and conifer soil moisture levels. Many linear aspen stands occur along streams (as at Crow Gulch), and canyon bottom or wet-site aspen is generally larger and more robust than its dry-site or steep-slope form. Because of this, a comparison of CG bird density and diversity with that of Black Mountain (BM), where no surface water is found, proves interesting (see Table 2). The BM study showed more species of breeding birds, so lack of surface water did not affect the diversity of birds; but it did show a reduced density of birds which may be an effect of surface water. Plotting diversity and density along a moisture gradient for the three areas, a good density-moisture relationship is shown, particularly for the wet site-dry site comparisons on the South Mueller Ranch (SMR), and low vs. high elevations at BM. Species numbers show a similar relation to moisture within those two areas, but not between the study areas.

Table 2. Comparison of moisture with breeding bird richness and density in the three aspen areas.

Moisture gradient	Number of species	Bird Density pairs/ha.
Dry site	SMR 5	3.0
	BM 14	3.7
Moist ground	SMR 10	7.5
	BM 24	6.0
Surface water	CG 16	10.0

In comparing bird diversity and density to the relative amount of exposure or slope difference, no strong relationship is found.

ASPEN VEGETATION

The yearly growth cycle of deciduous aspen allows much sunlight to hit the forest floor from the time of leaf fall in September until full leafing out in late June. This in turn allows the growth of understory vegetation, in varying amounts in the different stands, which in turn has led to classification of stand types based upon the plant species therein (Young 1977, and Severson and Thilenius 1976). A great variety of shrub and herb species can be found. Morgan (1969) summarized 25 understory types and other variations between stands near Gunnison, Colorado.

During the heat of the summer months the aspen leaf canopy has a moderating effect on both temperature and moisture of the forest floor as compared to the neighboring meadows. Not only humans find the stands inviting them, so do cattle and elk. And if you spend much time there, you quickly learn that insects prefer it too. It becomes difficult to move about without an insect repellant. Nestling birds that are exposed are heavily parasitized by mosquitos, and flies. Conifer stands are poorer in insect fauna (von Haartman 1971).

Because young birds are fed a high protein insect diet, regardless of the parents' food preference, and food supply has been said to govern the choice of breeding sites (Lack 1968, and Orians 1971), it seems possible that the varied understory plants provide food sources for varied insect species, which in turn serve as food for the breeding birds. To investigate this, I took sweep samples from aspen understory paired with ones from the less diverse meadow vegetation, for three breeding seasons in Crow Gulch. Although the data need further analysis, insects from aspen understory show greater diversity, larger size, and greater numbers during the June bird breeding peaks than insects found in the meadows (see Figures 1 and 2).

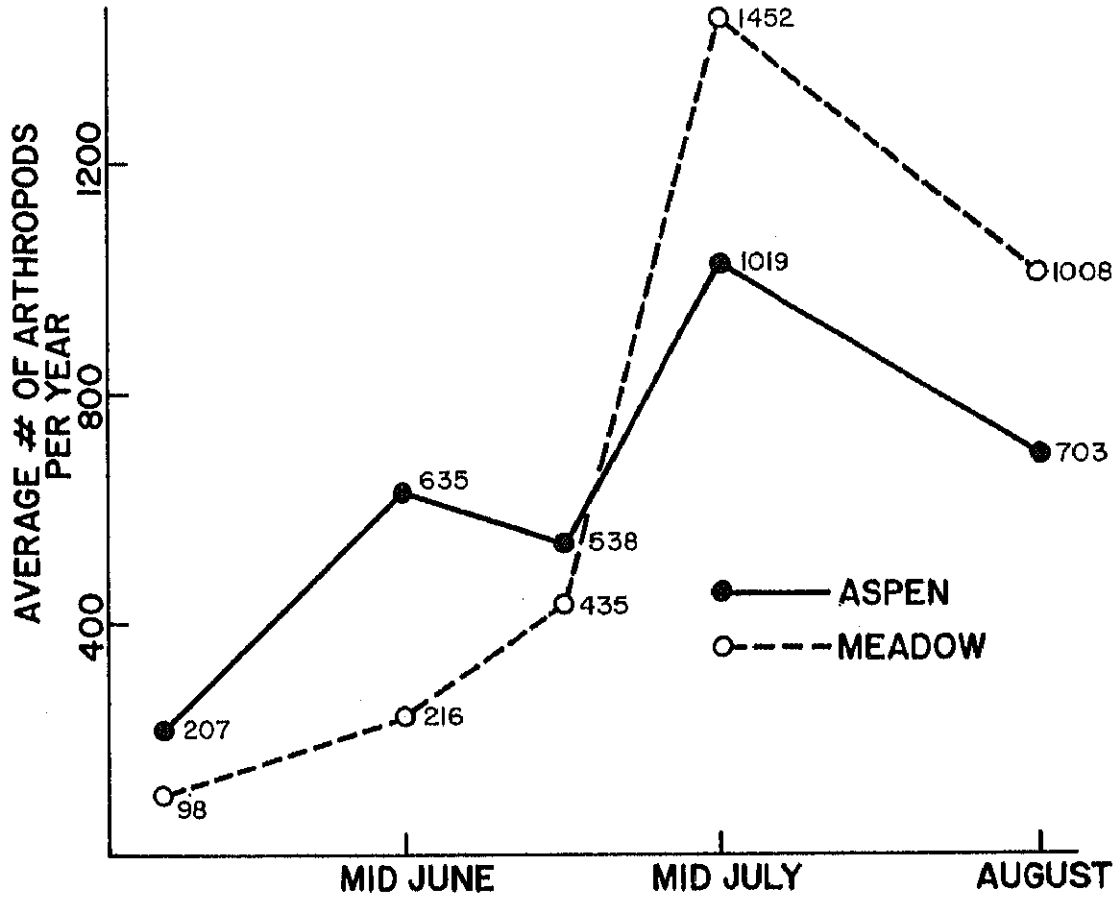

Figure 1. CROW GULCH ARTHROPOD SWEEP SAMPLES COMPARING ASPEN FLOOR AND OPEN MEADOW NUMBERS. (Three summers data)

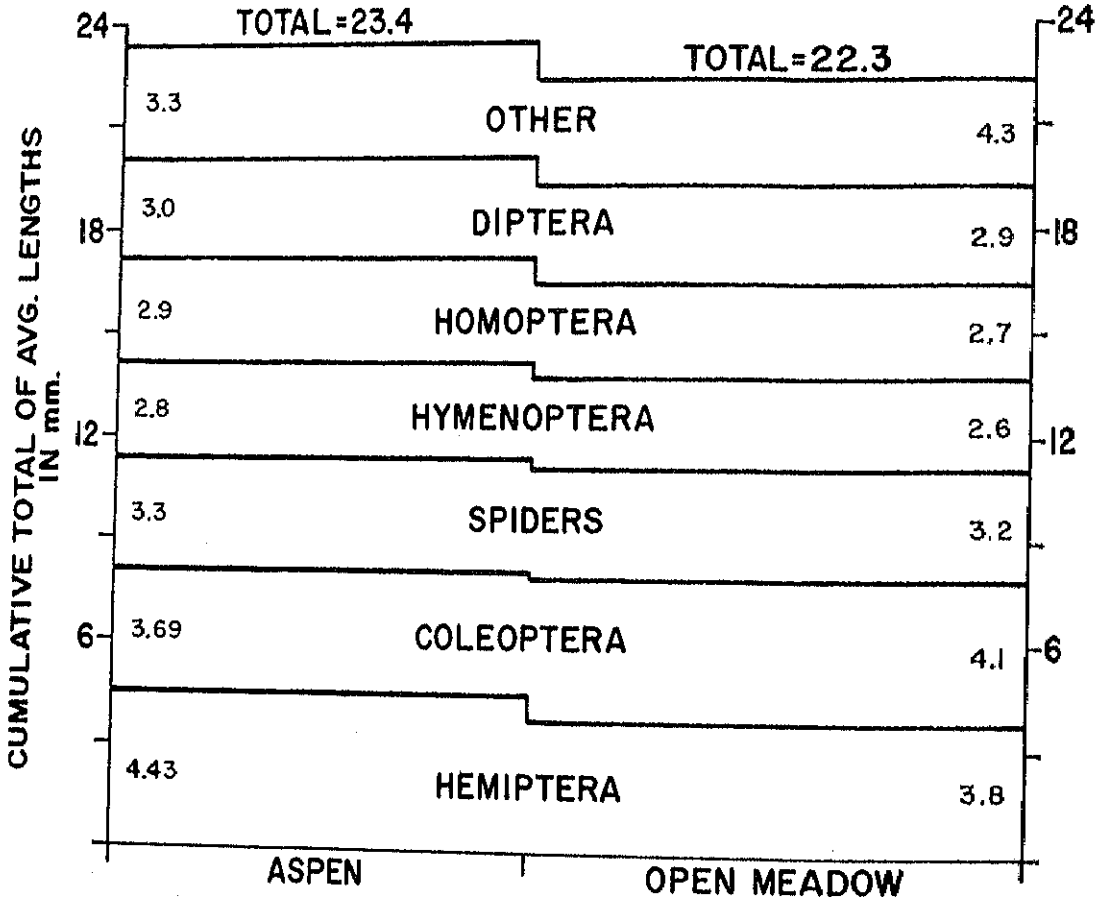

Figure 2. AVERAGE BODY LENGTH OF CROW GULCH ARTHROPODS, BY ORDERS IN A CUMULATIVE LIST.
(Three summers data)

Another aspect of aspen vegetation is the pronounced "edge effect" of the change from aspen stand into meadow. It is partly due to the clonal nature of aspen, and partially to cattle and elk utilization of young aspen shoots at the edge. The "edge" of forest was said to be richer in bird use than the forest interior (Johnston 1947). The Black Mountain stands have clear and distinct margins which can be used to weigh the possible importance of "edge".

Table 3 shows the division of bird density into edge and nonedge nesters, and the number of species in each category. While four species clearly use edge nesting locations, twelve species do not, and three more species use both edge and interior sites (I chose only the most common species to analyze here, with more than one nesting location known). While influence of "edge" on species diversity is not clear, it does appear that there is a higher density of breeding pairs at the edge in both the species limited to edge and those species which use both edge and interior. Thus edge does influence density.

Table 3. Number and density of Black Mountain bird species with preference for nesting on edge or in interior of stand.

Location	Number of species	Breeding pairs/ha.	Diversity	Density
Edge within 30 m.	4	0.75 0.66 0.5 0.25	low	.634 for edge species
Some edge preference	3	edge 1.12 interior 0.25 0.66 0.25 0.5 0.17		
No edge preference	12	7 at 0.25 1 at 0.5 1 at 0.12 2 at 0.06 1 at 0.03	high	.213 for interior species

OTHER BIOTIC EFFECTS

Many of the montane birds require nestholes for breeding, and most of these species cannot drill their own hole. Therefore the activities of woodpeckers and sapsuckers directly affect the density, and perhaps the diversity, of the secondary holenesters who cannot drill nestholes (see Scott et al. 1977 for data on these spps). The influence of hole availability on breeding levels was discussed by von Haartman (1971); and Balda (1975) estimated that nearly three hole trees per acre were needed to maintain breeding populations in Arizona ponderosa pine stands. During a study of aspen nesthole trees in Crow Gulch I found a strong correlation between bird density and such trees, as well as the incidence of heartrot fungus infection, as evidenced by conks of Fomes igniarius on the trees. Many authors have suggested that woodpecker species favor drilling in trees infected by heartrot (Conner 1977, Crockett and Hadow 1975, and Kilham 1971). In order to understand the influence of Fomes on bird density and diversity, one hectare of the Black Mountain study area was chosen at random for analysis. All aspen within it were inspected for visible Fomes conks and/or bird drilling activity. Affected trees were measured and marked, and

will be watched for both spread of the infection and new bird drilling. Although i is still too early to tell much, a few interesting facts have appeared. Fomes infected about 13% of the aspen (high for Pike National Forest, see Juzwik et al. 1978, who gave a 1.1% frequency). It was not a random infection, as groups of larg older aspen were infected, such groups being separated by healthy trees, and not al old large aspen were diseased. A summary of nesthole-Fomes data is presented in Table 4.

Table 4. Relationship between Fomes fungus infection and bird nestholes at Black Mountain. Diameter breast high given in cm.

Fomes conks	$\bar{x}$ DBH	Av. DBH nesthole trees	Number nesthole trees	Number nesthole
Present n = 170	20.6 cm.	25.6 cm	9	15
Absent n = 13	19.7	22.9	4	5

Morgan (1969) estimated most aspen fall into the 10 to 18 cm. DBH class, with few individuals exceeding 25.4 cm. These data show that Fomes infected the larger individuals, and the birds preferred the large infected trees for nestholes. It also shows they drill more holes per tree in the infected trees. It may be important to note that the ratio of live to dead trees in both categories was 2 to 1. There were aspen of all sizes and ages present in the study area. Young (1977) found the diversity of DBH measurements was predictive of bird species diversity, but not so much of bird density. She found that stands of many age groups of aspen, and therefore containing the older trees, were richest in birds.

In the Black Mountain area as a whole, 37.5% of the breeding species nested in holes. This agrees well with Balda (1975) who estimated 32 to 45% of the breeding species of montane birds were hole-nesters. In Hectare II, where the fungus infection/hole nesting relationship is being studied, a full 50% of the species found are hole-nesters, and the actual density figures should also prove close to 50%. Primary hole-nesters by species show up at 14%, but their density would be much less. This seems to indicate that Hectare II is very rich in secondary hole-nesting species. This relationship may be affected by ground moisture and edge, but how much it is so affected is as yet unknown. So far, it seems there is a definite species and number enrichment in Fomes infected areas.

The other biotic effect that I would like to briefly discuss is the variability in breeding bird feeding habits. It was shown at Crow Gulch that aspen birds space their breeding activity throughout late spring and the summer months in a way that reflects a partitioning of the food resources available. They also showed a balance in the methods of food gathering used (Winternitz 1973). The nesting period puts a special strain upon the parent birds to find adequate food for themselves as well as feed their offspring. Since birds of the same species defend breeding territories, competition within the species is low once a territory is established. I speculate that the major competition during the breeding season is between species with similar feeding habits. If this is true, and we knew more about the actual food items being used by these species, we could then look at the fluctuations in insect samples such as were taken in Crow Gulch and understand the mechanics of food partitioning.

SUMMARY

Both bird density and diversity in winter are very low in aspen. Mixed feeding flocks may give the appearance of high density or diversity, but the numbers of species and of birds per hectare are low.

Breeding bird densities and diversity in aspen are higher than in other montane vegetations. Comparing the results gathered in three study areas where various factors are somewhat controlled, it appears that breeding bird density in aspen is related to:

- surface water and ground moisture levels
- large and numerous insects in the aspen understory
- edge effect
- nesthole availability, depending on primary hole-nester activity and *Fomes* infection.

It is not as much related to:

- amount of slope exposure
- foliage height diversity
- foliage development.

Breeding bird diversity, depicted by species numbers, is related to:

- levels of ground moisture
- large and numerous insects in aspen understory
- nesthole availability, and *Fomes* infection

and not to:

- surface moisture
- foliage height diversity
- amount of slope exposure.

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NONGAME BIRDS OF THE ROCKY MOUNTAIN SPRUCE-FIR FORESTS AND THEIR MANAGEMENT

Kimberly G. Smith

Department of Biology and Ecology Center UMC 53
Utah State University, Logan

ABSTRACT

Spruce-fir forests in the Rocky Mountains consist mainly of Engelmann spruce and subalpine fir. The breeding avifaunas in these forests show remarkable consistency in composition along a latitudinal gradient from Montana to Arizona and New Mexico, and with avian communities in the Hudsonian life zone in Washington, Oregon, and California. Woodpeckers, corvids, and seed-eating finches are the most common components. Only the Golden Eagle and a few other raptors are threatened or endangered. Few species winter in these high mountain forests.

The distribution of many species is controlled primarily by the vegetation physiognomy, a variable under the control of the forest manager. Fire control and snag management will generally benefit the avifauna, whereas most forest harvesting practices adversely affect, to differing degrees, the bird communities. It is suggested that the "life-form" approach to avian communities may be easily implemented in these forests. It is recommended that high elevation spruce-fir forests be minimally harvested and used as reservoirs for spruce-fir birds. Lower elevational stands should be managed for harvesting and bird diversity, with special attention given to relic stands.

KEYWORDS: Engelmann spruce, forest management, life-form approach, logging, spruce-fir avifauna, subalpine fir.

tern United States, true spruce-fir forests which are found only at lons in the Rocky Mountains and central Washington and Oregon are led as climax forests. In the Rockies, these forests have generally for many hundreds, if not thousands, of years, occurring where remote- ain, and relatively low timber values have discouraged exploitation conditions have kept fires to a minimum (Marr 1967). The avifaunas these forests are well-known and show remarkable consistency from next, but little ornithological research has been done in these y due to their remoteness.

Spruce-fir forests are some of the most extensive and most productive timber resources in the Central Rocky Mountains, as well as important watersheds, providing habitats for a wide variety of wildlife, forage for livestock, and recreational opportunities and scenic beauty (Alexander 1977). As we approach the 21st century, these forests will come under increasing pressure for all these interests, so it is imperative that guidelines be established or reevaluated for management of both the forests and the associated nongame wildlife. In this report, I review the literature concerning the avifauna of western spruce-fir forests, discuss the relationships between the avifauna and the spruce-fir forests, and suggest some management options that may benefit the nongame bird species.

THE SPRUCE-FIR FOREST

Forest Description

ROCKY MOUNTAINS

The dominant tree species of the spruce-fir forest of the Rocky Mountains are Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa). Other tree species that are often associated with spruce-fir forests in the Rockies are aspen (Populus tremuloides), lodgepole pine (Pinus contorta), and Douglas-fir (Pseudotsuga menziesii). Spruce-fir forests generally occur in the coldest, wettest, and highest areas of the Mogollon Plateau, White and San Francisco Mountains, and Kaibab Plateau in Arizona (Merkle 1954); the higher mountains of northern New Mexico; the Rocky Mountains through Colorado (Marr 1967), Wyoming, Idaho and western Montana; and the Uinta and Wasatch Mountains in Utah (Hayward 1945)(Fig. 1).

Typical old spruce-fir stands are homogeneous and simple, having a dominant spruce overstory with a fir understory (Whipple and Dix 1979), with few other tree species present since none can germinate in the shade of spruce and fir (Marr 1967). The shrub and herb layers are poorly developed (Merkle 1954, Marr 1967, Schimpf et al. 1980), but wind throw and fallen trees (both living and dead) are common (e.g., Rasmussen 1941, Loope and Gruell 1973), sometimes making passage through a spruce-fir forest a "tedious and tiresome activity" (Marr 1967). More specific information concerning vegetational characteristics of these spruce-fir forests may be found in Peet (1978), Whipple and Dix (1979), Schimpf et al. (1980), and references therein.

CASCADES AND SIERRA NEVADA

Engelmann spruce-subalpine fir forests occur on the east slope of the Cascades in Washington and Oregon, the Okanogan Highlands of northeastern Washington, and the Blue and Wallowa Mountains in northeastern Oregon and southeastern Washington (Fig. 1). These forests are typically found in frost pockets and other habitats characterized by draining and accumulation of cold air, such as glaciated valley bottoms (Franklin and Dyrness 1973). Franklin and Dyrness (1973) concluded that subalpine fir is the major and often sole climax species in these forests. Many tree species are associated with subalpine fir forests in this region, and the ecological associations and successional relationships of these areas are much more complex than in the spruce-fir forests of the Rockies.

In the Sierra Nevada, white fir (Abies concolor) and California red fir (A. magnifica) predominate in Merriam's Hudsonian Life Zone (Fig. 1), which is analogous to the Abies lasiocarpa Zone of Washington and Oregon and the spruce-fir forests of the Rockies (Franklin and Dyrness 1973). No spruce species occurs in the Sierra Nevada.

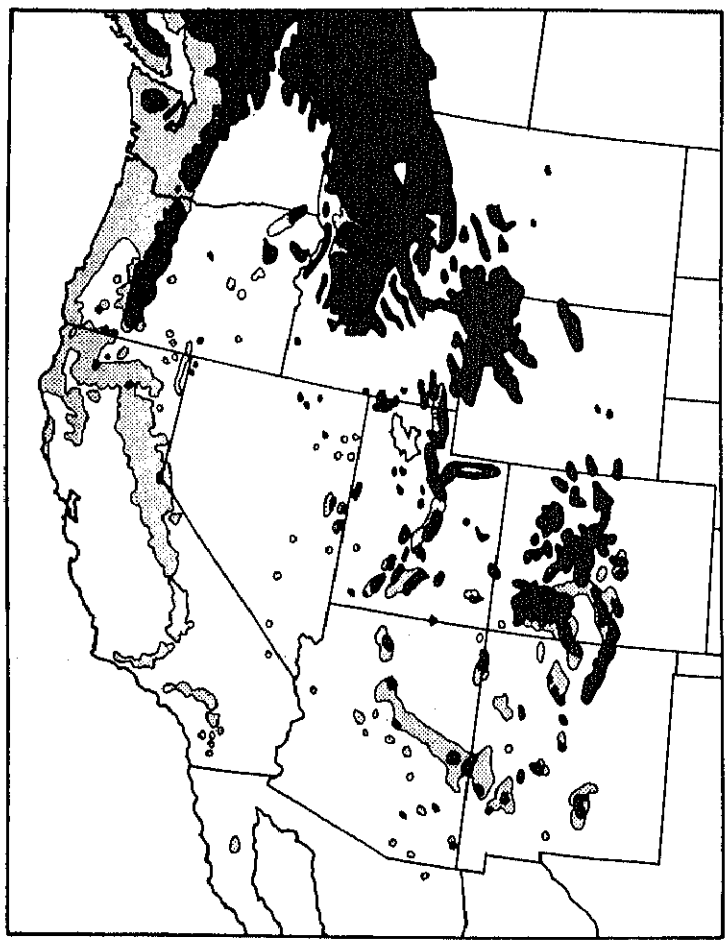

Figure 1.--Distribution of spruce and firs in the western United States. Dark areas depict the range of Engelmann spruce and subalpine fir in the Rocky Mountains (which is the emphasis of this paper) and in the Abies lasciocarpa Zone (Franklin and Dyrness 1973) of Washington and Oregon. Stippled areas in the Northwest show range of Sitka spruce (Picea sitchensis) and Pacific silver (Abies amabilis), grand (A. grandis), and noble (A. procera) firs where they occur outside of the Engelmann spruce-subalpine fir range. Stippled areas in the Sierra Nevada show the range of white and California red firs in the Hudsonian Life Zone. Stippled areas in the Southwest are patches of white fir. The range of blue spruce (P. pungens) is completely within the range of Engelmann spruce. Map adapted from Little (1971).

Forest Succession

The climax spruce-fir forests are often complex mosaics of various seral stages (Habeck and Mutch 1973) due to effects of weather, fire, infestations, etc. Whipple and Dix (1979) advise caution in using the term climax for spruce-fir forests, suggesting that a more appropriate statement would be that these forests are relatively unchanging and appear to be perpetuating themselves. Because of short growing seasons and low temperatures where these forests occur, natural processes are slow and it is possible that spruce-fir forests actually cycle every 500-1000 years, a scale too long for human perception (see, e.g., Bloomberg 1950).

Since several pathways may be possible in the same region, depending on climatic and edaphic conditions, elevation, and seed sources (see Schimpf et al. 1980), vegetation recovery following a disturbance is difficult to predict in spruce-fir forests (Habeck and Mutch 1973). Where spruce-fir forests are destroyed at lower elevations, aspen or lodgepole pine usually invade first. The shade of these trees facilitates the germination of spruce and fir and both species are usually found in lodgepole stands within 60-105 years (Whipple and Dix 1979). Subalpine fir can replace a lodgepole pine stand in 250-400 years (Loope and Gruell 1973); Billings (1969) has estimated that it takes 6-7 centuries to obtain a pure spruce-fir stand with 300-500 year old trees. Engelmann spruce tends to dominate such stands since it lives much longer than subalpine fir (Whipple and Dix 1979), although subalpine fir may, in certain situations, be the true climax (see Franklin and Dyrness 1973).

At high elevations, either subalpine fir or Engelmann spruce can replace a destroyed spruce-fir forest (if no aspen roots are present to sucker) within several centuries (Billings 1969). However, subalpine fir does not grow or reproduce as well at high elevations (Whipple and Dix 1979). Billings (1969) points out another possibility: if the removal of a spruce-fir forest changes the snow drift pattern so that late-lying snowbanks form, coniferous seedling establishment becomes impossible and no reforestation will occur.

THE SPRUCE-FIR AVIFAUNA

Species Composition

BREEDING AVIFAUNA

In the Rocky Mountains, one generally is impressed with the consistency of the spruce-fir avifauna during the breeding season as one moves south from Montana to Arizona and New Mexico (Table 1). Twenty-one of 48 species were reported in 5 or more of the 10 studies listed in Table 1. Mountain Chickadee, Ruby-crowned Kinglet, Yellow-rumped (Audubon's) Warbler, Pine Siskin, and a junco occurred in all studies, Hermit Thrush, Clark's Nutcracker in 9, and Hairy Woodpecker, Red-breasted Nuthatch, and American Robin in 8 (see Table 2). Based on this consistent pattern, Hubbard (1965) concluded that the spruce-fir avifauna of the Mogollon Mountains in New Mexico had Rocky Mountain affinities, and Carothers et al. (1973) concluded that the spruce-fir avifauna of the White Mountains in Arizona were more closely related to spruce-fir avifauna in Colorado and Wyoming than to the Chiricahua Mountains only 150 miles to the south. The similarity of the avifaunas indicated in Table 1 is undoubtably an underestimate since most studies did not report non-passerines (except woodpeckers), and studies were conducted for various lengths of time (e.g., 1 breeding season [Snyder 1950] to 30 consecutive months, 3 breeding seasons [Smith 1980]). (Only species recorded in 2 or more studies were included in Table 1, with 14 additional species that were recorded only once deleted.)

Table 1.--Bird species observed during the breeding season in spruce-fir forests in at least 2 studies along a latitudinal gradient in the Rocky Mountains. MT=Montana, WY=Wyoming, CO=Colorado, UT=Utah, AR=Arizona, NM=New Mexico. Montane birds of the Intermountain Region (IM) and the North American boreomontane forest (BF) are included for comparison.

SPECIES	SCIENTIFIC NAME	MT[1]	WY[2]	CO[3]	UT[4]	UT[5]	UT[6]	AR[7]	AR[8]	NM[9]	NM[10]	IM[11]	BF[12]
TURKEY VULTURE	Cathartes aura				X				X		X		
GOSHAWK	Accipiter gentilis				X					X			
COOPER'S HAWK	A. cooperii	X			X								
SHARP-SHINNED HAWK	A. striatus				X				X				
GOLDEN EAGLE	Aquila chrysaetos	X			X								
AMERICAN KESTREL	Falco sparverius	X						X	X				
BAND-TAILED PIGEON	Columba fasciata									X	X		
GREAT HORNED OWL	Bubo virginianus				X		X						
BROAD-TAILED HUMMINGBIRD	Selasphorus platycercus				X		X		X	X	X		
COMMON FLICKER	Colaptes auratus	X		X	X		X	X	X		X		
WILLIAMSON'S SAPSUCKER	Sphyrapicus thyroides				X			X			X		
HAIRY WOODPECKER	Picoides villosus		X	X	X	X	X		X	X	X	X	
DOWNY WOODPECKER	P. pubescens									X	X		
NORTHERN 3-TOED WOODPECKER	P. tridactylus		X		X			X	X	X	X		
DUSKY FLYCATCHER	Empidonax oberholseri	X			X			X			X	X	X
WESTERN WOOD PEWEE	Contopus sordidulus				X						X		X
OLIVE-SIDED FLYCATCHER	Nuttallornis borealis		X					X					
STELLER'S JAY	Cyanocitta stelleri				X			X	X	X	X		
GRAY JAY	Perisoreus canadensis					X	X		X				
BLACK-BILLED MAGPIE	Pica pica	X			X								
CLARK'S NUTCRACKER	Nucifraga columbiana	X	X	X	X	X	X		X	X	X	X	
COMMON RAVEN	Corvus corax				X				X		X		
MOUNTAIN CHICKADEE	Parus gambeli	X	X	X	X	X	X	X	X	X	X	X	X
WHITE-BREASTED NUTHATCH	Sitta carolinensis				X			X			X	X	X
RED-BREASTED NUTHATCH	S. canadensis	X	X		X	X	X		X	X	X		
BROWN CREEPER	Certhia familiaris		X		X	X	X		X	X	X		X
HOUSE WREN	Troglodytes aedon							X		X	X		X
AMERICAN ROBIN	Turdus migratorius		X		X	X	X	X	X	X	X	X	
TOWNSEND'S SOLITAIRE	Myodestes townsendi	X		X	X		X	X	X		X		X
HERMIT THRUSH	Catharus guttata	X	X	X	X		X	X	X	X	X	X	X
SWAINSON'S THRUSH	C. ustulata	X	X										X
MOUNTAIN BLUEBIRD	Sialia currucoides	X						X				X	
GOLDEN-CROWNED KINGLET	Regulus satrapa	X	X		X				X	X			X
RUBY-CROWNED KINGLET	R. calendula	X	X	X	X	X	X	X	X	X	X		X
WARBLING VIREO	Vireo gilvus				X			X		X	X		X
ORANGE-CROWNED WARBLER	Vermivora celata				X								X
YELLOW-RUMPED WARBLER	Dendroica coronata	X	X	X	X	X	X	X	X	X	X	X	X
WESTERN TANAGER	Piranga ludoviviana		X		X				X	X	X		
EVENING GROSBEAK	Hesperiphona vesputina							X					X
CASSIN'S FINCH	Carpodacus cassinii		X		X		X	X				X	X
PINE GROSBEAK	Pinicola enucleator	X	X	X	X	X	X					X	X
PINE SISKIN	Carduelis pinus	X	X	X	X	X	X	X	X	X	X		X
RED CROSSBILL	Loxia curvirostra	X		X	X				X	X	X		X
GREEN-TAILED TOWHEE	Pipilo chlorura								X		X	X	
DARK-EYED JUNCO	Junco hyemalis	X	X		X							X	
GRAY-HEADED JUNCO	J. caniceps			X		X	X	X	X	X	X		
CHIPPING SPARROW	Spizella passerina	X	X		X	X	X	X	X		X		
WHITE-CROWNED SPARROW	Zonotrichia leucophrys				X	X							
	TOTAL SPECIES	21	19	12	37	14	19	22	26	22	30	13	19

1/ Thompson 1978; alpine forest and spruce-lodgepole.
2/ Salt 1957; spruce-fir.
3/ Snyder 1950; spruce-fir.
4/ Smith 1980; spruce-fir. (also in Schimpf et al. 1980)
5/ Winn 1976; spruce-lodgepole.
6/ Austin and Perry 1979; spruce-lodgepole.
7/ Rasmussen 1941; spruce-fir.
8/ Carothers et al. 1973; spruce-fir, aspen.
9/ Hubbard 1965; spruce-fir.
10/ Tatschl 1967; spruce-fir.
11/ Johnson 1975; Intermountain boreal birds.
12/ Udvardy 1963; North American boreomontane.

For comparison, 13 species that Johnson (1975) termed the "western American boreal birds" in his study of the Great Basin mountain top "island" avifaunas, and 19 passerine species that Udvardy (1963) suggested were part of the North American boreomontane avifauna, are included in Table 1. Carbyn (1971), Theberge (1976) and Erskine (1977) present comparable data from the spruce-fir forests of western Canada.

Generally, the avifaunas in the Hudsonian Life Zone of the Sierra Nevada and the Cascade Mountains appear quite similar to those reported in Table 1 for the Rocky Mountains (see, e.g., Grinnell et al. 1930, Gabrielson and Jewett 1940, Jewett et al. 1953). The major differences between the two regional avifaunas are a replacement of the Northern 3-toed Woodpecker by the Arctic 3-toed Woodpecker (Picoides arcticus) due to the lack of spruce in the Sierra Nevada (Bock and Bock 1973), and the addition of Varied Thrush (Ixoreus naevius),Hermit (Dendroica occidentalis) and Townsend (D. townsendi) warblers to the Hudsonian Life Zone forests of the Far West.

In contrast to eastern spruce-fir forests where warblers (primarily the genus Dendroica) are the most common element of the avifauna (e.g., Sabo and Whittaker 1979, Titterington et al. 1979), western spruce-fir forests have few warblers (e.g., Wiens 1975), but many woodpeckers, corvids, and finches (Table 1). This suggests that unlike eastern forest avifaunas which primarily key on foliage insects, western spruce-fir avifaunas are adapted to old-growth stands where "infaunal" insects are more plentiful (Haapanen 1965, Nilsson 1979). Foliage insects and ground invertebrates are relatively rare in western spruce-fir forests (e.g.,Hayward 1945). Also, cone crops are larger in the west; Engelmann spruce usually produces large cone crops (>200 cones/tree) at frequent intervals (Franklin 1968).

The number of breeding species reported ranged from 12 (Snyder 1950) to 27 (Smith 1980). Reported total densities ranged from 134 individuals/40ha in mature lodgepole-spruce (Austin and Perry 1979) to 170-187 pairs/40ha in spruce-fir and aspen (Carothers et al. 1973) to 210 pairs/40ha in the spruce-fir of New Mexico (Tatschl 1967). As mentioned before, some of these discrepancies are due to the different ways in which the studies were conducted. Topography will influence the distribution of some species, such as Turkey Vulture, Golden Eagle, and White-throated Swift (Aeronautes saxatalis), which depend on cliffs for nesting, and, as will be discussed later, the physiognomy of the plots themselves will influence the distribution of certain species. World-wide, there are generally 20-30 species of birds present in any spruce forest (Schimpf et al. 1980).

WINTER AVIFAUNA

Few species spend the winter months in high-elevation climax coniferous forests in western North America, since these forests are located where winters are severe and food is scarce. For example, of the 250 avian species that breed in the coniferous forests of western Canada, only 45 species winter in that area (Erskine 1977). Not many species winter in the spruce forests in northern Europe (Hannson 1979) presumably for the same reasons.

Species that do spend the winter in spruce-fir forests usually travel in small, mixed-species flocks (e.g., chickadees, nuthatches, siskins), and occur in "pockets" (Wing 1950). Thus, one may walk (or ski) for several kilometers without hearing or seeing any birds, then find a small area of great bird activity.

Haapanen (1965) concluded (as have others) that winter mortality due to food supply and/or severe weather is the most decisive factor limiting permanent resident populations in spruce-fir forests. Most species are adapted to withstand the severe weather, either behaviorally (e.g., via communal roosting) or physiologically

(e.g., hypothermia [Haftorn 1972, Chaplin 1974, Andreevan 1979]). There is relatively little forest managers can do to shield the birds from severe weather.

However, managers can insure that forests contain maximum food resources. Woodpeckers are generally more dependent on dead trees in winter. Males and females of the same species may also use different tree species for obtaining food resources (e.g., Hogstad 1976,1977). Some species, such as Mountain Chickadees (Haftorn 1974) and Red-breasted Nuthatches (personal observation), cache food (arthropods and seeds) in trees during late summer and fall for winter consumption, but most insectivores are dependent on spiders (Askenmo et al. 1977) and insect eggs. Seed-eating finches and jays search out large cone crops. All these feeding requirements suggest again the dependence of the avifauna on old-growth spruce-fir forests.

HOLE-NESTING SPECIES

The recent interest in hole-nesting species and snag management (reviewed in Raphael and White 1978) is pertinent to management of spruce-fir forests. Of all the woodpeckers found in spruce-fir forests, apparently only the Northern 3-toed Woodpecker is capable of making holes in the dense wood of living spruce trees (Haapanen 1965). Therefore, other hole-making species are dependent on either snags, aspen, or to some extent fir trees. Haapanen (1965) reported that in a stand composed of 90% spruce, only 8 of 76 nesting holes occurred in spruce trees. Likewise, in a western larch (Larix occidentalis)-Douglas-fir forest in Montana, McClelland et al. (1975) found only 2 of 83 active snag nests in Engelmann spruce.

Understandably, there are fewer secondary-cavity nesters (birds dependent on other species to excavate cavities) associated with spruce-fir forests than with, say, an aspen grove (see Smith 1980). Only 6 species of secondary-cavity nesters are listed in Table 1 - American Kestrel, Mountain Chickadee, White-breasted Nuthatch, Red-breasted Nuthatch, House Wren, and Mountain Bluebird. (Although not reported, I suspect that some of the western owls which are secondary-cavity nesters, e.g., Pygmy Owl [Glaucidium gnoma], Flammulated Owl [Otus flammeolus], also rarely occur in western spruce-fir forests.) Only the Mountain Chickadee and Red-breasted Nuthatch occur commonly and both are capable of excavating their own nesting cavities (Scott et al. 1977). Haapanen (1965,1966) concluded that in old forests the number of hole-nesters decreases at the same rate as the forest changes into pure spruce.

SEED-EATING SPECIES

Seed-eating species, primarily cardueline finches and corvids, are common and wide-ranging in western spruce-fir forests. Cone crops may primarily determine the density of some of these species (Haapanen 1966). Most tend to be nomadic, appearing whenever large cone crops exist (e.g., Smith 1978). Godfrey (1966), discussing the Red Crossbill stated: "Nesting time is as erratic as its wanderings and may occur in any month of the year. The breeding range is not well known. Its presence in an area is no guarantee that it is breeding there. Its nesting in a given area is no indication that it will nest there next year or in the next decade, or that it nested there last year". The male of many of these finches defends a territory around a female, so that the abundance of females determines the breeding densities (along with cone crop), and not suitable habitat (Samson 1976, Smith 1978). Furthermore, in times of cone surfeit, species not normally associated with coniferous cones, such as Common Redpolls (Carduelis flammea), may feed on them (Smith 1979).

Most people associate the presence of these seed-eating species in the United States with periodic winter eruptions from the northern boreal forests of Canada. However, in analyzing the pattern of these eruptions, Bock and Lepthien (1976) cautioned that frequently populations of seed-eating birds in coniferous forests

of the western United States do not erupt in synchrony with those species occurring in the northern boreal forest. This is probably due to the several different options available to the seed-eating birds in the Rockies - they can move south, north, or elevationally in search of seed crops. Bock and Lepthien (1976) conclude that the appearance of unusual numbers of a species during winter in western areas usually does not represent an eruption, although this is not always the case[1/].

RARE AND ENDANGERED SPECIES

The only endangered species associated with the western spruce-fir forests is the Golden Eagle. Although most eagle nests are placed on cliffs, some do occur in conifers, and eagles frequently hunt within the spruce-fir ecosystem. Forest harvesting and eagle nesting are probably incompatible; in the mountains of New Mexico and western Texas, 85% of nest failures were due to human disturbance (Boeker and Ray 1971). However, the presence of small clear-cut openings may be beneficial for foraging since more raptors tend to be observed around clear-cuts than in the forest (Winn 1976). These clear-cut areas would possibly benefit other rare raptors, such as Merlin (Falco columbarius) (reported in Thompson 1978), Cooper's, and Sharp-shinned hawks, all of which may be declining in western United States (Arbib 1978). I suspect that Peregrines (Falco peregrinus) may also occasionally use the spruce-fir clearing for feeding.

Goshawks are rare in spruce-fir forests and their presence seems dependent on large aspen trees within the forest for nesting (personal observation) since spruce trees apparently cannot support the weight of their large nest (Haapanen 1966). As suggested earlier, several small owls may be rare in the western spruce-fir forests, but I found no abundance estimates. Proper snag management probably would be beneficial to small owls.

With the possible exception of the Mountain Bluebird (Arbib 1978), all passerines (including those deleted from Table 1) found in spruce-fir forests of western United States are relatively common, although they may of course be locally rare in certain areas due to such factors as zoogeography, elevation, and climate (see Johnson 1974, Smith[2/]).

FORAGING TYPE STRUCTURE

Referring to the "western American boreal birds" of the Intermountain area, Johnson (1975) stated that each species within this group was fundamentally different in its place or style of feeding, and even in the simplest communities, there were fundamental foraging roles that were always performed, usually by the same species. Thompson (1978) reached the same conclusion concerning a standard set of montane species, and offered the explanation that the addition of a coniferous forest layer increases to near maximum the number of guilds (= foraging types), whereas adding more species of conifers results in expansion within these guilds. This pattern of fundamental guilds is probably characteristic of the entire western spruce-fir ecosystem. Considering the 16 most common species from Table 1, few foraging type members show a similar preferred foraging substrate (Table 2). Almost all the other species (excluding raptors) listed in Table 1 fall into the foraging types defined by these first

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[1/]Vander Wall, S. B., W. K. Potts, and S. Hoffman. Eruptive behavior of Clark's Nutcracker. Unpublished Manuscript. Utah State University

[2/]Smith, K. G. The effects of an extreme drought on a temperate subalpine bird community. Unpublished manuscript. Utah State University.

16 species. For example, comparing the species reported in 5 studies from Table 1 with those reported in more studies (Table 2), Red Crossbill is similar in foraging type and substrate to Pine Siskin, Western Tanager to Yellow-rumped Warbler, and Golden-crowned Kinglet to Mountain Chickadee. Steller's Jay is termed an omnivore, but probably overlaps greatly with Clark's Nutcracker, Hermit Thrush, and Pine Grosbeak.

TABLE 2.--The 21 most commonly reported bird species in Rocky Mountain spruce-fir forests (from 10 field studies listed in Table 1), their foraging type, and preferred foraging substrate.

Species	Number of Studies	Foraging Type	Foraging Substrate
Mountain Chickadee	10	Foliage-Insect	Fir
Ruby-crowned Kinglet	10	Foliage-Insect	Spruce
Yellow-rumped Warbler	10	Foliage-Insect	Forest
Pine Siskin	10	Foliage-Seed	Spruce
Junco sp.	10	Ground-Insect/Seed	Openings
Clark's Nutcracker	9	Foliage-Seed	Pines
Hermit Thrush	9	Ground-Insect	Forest
American Robin	8	Ground-Insect	Openings
Red-breasted Nuthatch	8	Timber-Search	Dead Trees
Hairy Woodpecker	8	Timber-Drill	Spruce-Fir
Chipping Sparrow	7	Ground-Insect/Seed	Forest
Townsend Solitaire	7	Ground-Insect/Seed(?)	(?)
Brown Creeper	7	Timber-Search	Live Trees
Common Flicker	6	Ground-Insect	Openings
Northern 3-toed Woodpecker	6	Timber-Drill	Spruce
Pine Grosbeak	6	Ground-Insect/Seed	Forest
Red Crossbill	5	Foliage-Seed	Spruce
Steller's Jay	5	Omnivore	Forest
Western Tanager	5	Foliage-Insect	Spruce-Fir
Golden-crowned Kinglet	5	Foliage-Insect	Fir
Broad-tailed Hummingbird	5	Nectivore	Openings

An analysis of the foraging type structure (excluding raptors) of the spruce-fir avifauna on a latitudinal gradient from Montana to Arizona and New Mexico (Table 3) demonstrates again the relative consistency of these avifaunas, but reveals some interesting trends. Aerial feeders form a relatively small component of the spruce-fir avifauna, primarily because soaring species, e.g., White-throated Swift, Violet-green Swallow (Tachycineta thalarina), do not ordinarily nest in spruce-fir forests, and sallying flycatchers do not often hunt from perches in the closed canopy of the spruce-fir forest (personal observation). Sallying flycatchers prefer forests with open understories (e.g., Smith 1977) or forest edges. The nectivorous Broad-tailed Hummingbird is rare due to the paucity of flowers in the spruce-fir forest (Schimpf

et al. 1980), and the omnivores (jays and crows) are also a minor component. Collectively, these 3 foraging types average less than 13% of the total number of species in the spruce-fir avifaunas.

TABLE 3.--The foraging type structure (excluding raptors) observed in the 10 field studies listed in Table 1. Numbers of species in each category are listed with percent of total species in each category in parentheses. The Intermountain Region avian foraging type structure is presented for comparison.

FORAGING TYPE	MT[1/]	WY	CO	UT	UT	UT	AR	AR	NM	NM	IM
AIR - PERCH/SOAR	2(11)	1(5)	0(0)	2(7)	0(0)	0(0)	4(18)	1(4)	0(0)	2(8)	2(14)
FOLIAGE - INSECT	4(21)	5(26)	4(33)	6(22)	3(21)	3(17)	5(23)	5(22)	6(33)	5(20)	3(21)
FOLIAGE - SEED	4(21)	2(21)	4(33)	5(18)	3(21)	4(22)	2(9)	2(9)	3(17)	3(12)	1(7)
TIMBER - SEARCH	1(5)	2(11)	0(0)	3(11)	2(14)	2(11)	1(5)	2(9)	2(11)	3(12)	1(7)
TIMBER - DRILL	0(0)	2(11)	1(8)	3(11)	1(7)	1(6)	2(9)	2(9)	3(17)	3(12)	1(7)
GROUND - INSECT	3(16)	3(16)	1(8)	3(11)	2(14)	3(17)	4(18)	3(13)	3(17)	3(12)	3(21)
GROUND - INSECT/SEED	3(16)	2(11)	2(17)	2(7)	2(14)	3(17)	3(14)	4(17)	1(6)	4(16)	3(21)
OMNIVORE	2(11)	0(0)	0(0)	1(4)	1(7)	1(6)	1(5)	3(13)	1(6)	1(4)	0(0)
NECTIVORE	0(0)	0(0)	0(0)	1(4)	0(0)	1(6)	0(0)	1(4)	1(6)	1(4)	0(0)
TOTAL BREEDING SPECIES	19	19	12	26	14	18	22	23	20	25	14

[1/] Order and abbreviations as in Table 1.

The other foraging types were also relatively consistent along the gradient (Table 3). A few timber-using species were found in each study area, averaging about 18% of the avifauna. Ground-feeders were common due to the open understory of spruce-fir forests. Gray-headed Juncos may be responsible for most Engelmann spruce first-year seedling mortality which had usually been attributed to rodents (Noble and Sheppard 1973). (Interestingly, the junco is also the only ground-nesting species associated with spruce-fir forests, the number of ground-nesters being low due to the lack of ground cover (Haapanen 1965).)

The foliage-seed foraging type tended to be better represented in the nothern studies, with only 2 members of this foraging type present in each of the Arizona studies. Foliage insectivores consistently accounted for about 25% of the avifaunas.

Referring to coniferous forests in general, Wiens (1975) hypothesized that most foraging opportunities exist in the outer zone of the canopies, where twigs and needles will support only small individuals or where food resources may be available only to small individuals. Most members of this foliage-insect foraging type in western spruce-fir forests are small. Wiens further suggested that foliage foraging types numerically dominate coniferous forest avifaunas, with ground-foraging, timber-foraging, and aerial feeders decreasing in importance in that order. This appears to be true for western spruce-fir forests.

On theoretical grounds, Valiela (1971) argued that during the course of succession, a trend in increasing feeding specialization would be expected, primarily through addition of avian insectivores and carnivores. The climax spruce-fir forest supports this observation. A myriad of carnivores is associated with the spruce-fir forest, but not with the earlier successional stages (e. g., aspen) and most species in the spruce-fir forests belong to the insectivorous foraging type (Table 3). (A complete treatment of the avian successional relationships in a western spruce-fir

forest can be found in Smith and MacMahon[3/].)

SPRUCE-FIR PHYSIOGNOMY AND AVIAN DISTRIBUTION

The physiognomy of most spruce-fir forests is probably the most important factor determining both the number of bird species present and their density, and also is the factor that forest managers have most control over. Forests with Engelmann spruce support some of the least diverse avifaunas of all the coniferous forests in the western United States (e. g., Hayward 1945); the number of bird species and densities decrease as spruce invasion increases (e. g., Haapanen 1965, Austin and Perry 1979).

Influence of Specific Vegetational Components

TREE LAYER

In discussing the role of habitat structure in avian community organization, Willson (1974) concluded (in part) that the mere presence of a tree layer is more closely associated with species addition than is the total amount of foliage or its distribution. Many species of birds occur throughout coniferous forests in western North America regardless of the tree species that dominate the plant community (Erskine 1977). Equally important to some birds of western spruce-fir forests, however, is the species composition of the tree layer. In general, all climax forests in North America are characterized by comparatively few birds (and mammals) except where these forests come in contact with subclimax vegetation (Shelford and Olsen 1935), and the spruce-fir forests of western United States are an excellent example of this phenomenon.

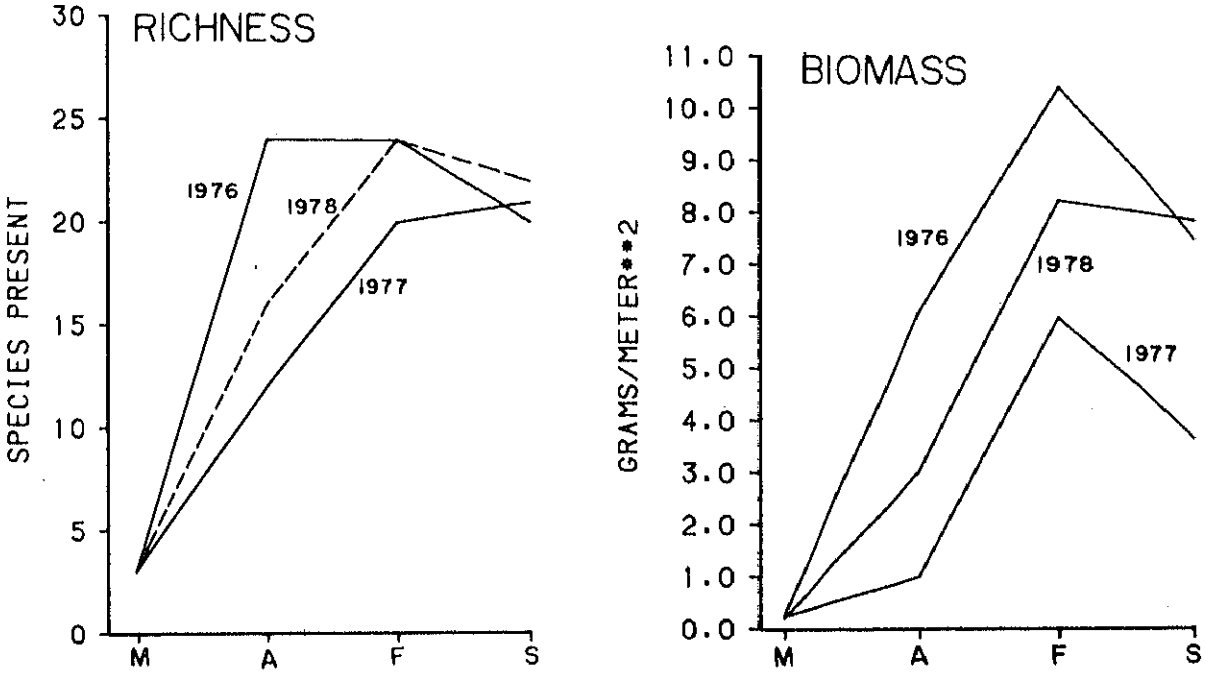
ASPEN

The amount of aspen within the spruce-fir forest will influence the distribution of species that use aspen for nesting, e. g., Goshawk, Downy Woodpecker, Mountain Bluebird, Violet-green Swallow, and feeding, e. g., Yellow-bellied Sapsucker (Sphyrapicus varius), Warbling Vireo, Orange-crowned Warbler. Sallying flycatchers, e. g., Western Wood Pewee, Dusky Flycatcher, tend to be associated with aspen since aspens usually grow within forest openings and have open canopies which the flycatchers can either sally in or under. In general, a patch of deciduous forest has an enriching effect on the avifauna of a coniferous forest (Winternitz 1976) and high avian species diversity is associated with an aspen-conifer overstory (Winn 1976).

SUBALPINE FIR

Subalpine fir can also have an enriching effect on a forest. Johnson (1978) found an increase in number of avian species at both the east and west side of the Great Basin correlated with the appearance of fir. When subalpine fir forests occupy the successional stage between aspen and climax spruce-fir, the number of bird species (Fig. 2) and avian biomass (Fig. 3) is usually much greater in the fir forest since the forest is a conglomeration of spruce, fir, and aspen. In this situation, the fir forest is a transition from deciduous to coniferous forest and species characteristic of both habitats are present.

[3/] Smith, K. G., and J. A. MacMahon. Bird communities in a montane sere: Community structure and energetics. Unpublished manuscript. Utah State University.



Figures 2 and 3.--Species richness and total annual avian biomass present during the breeding season in 1976, 1977, and 1978 in the Bear River Mountains of northern Utah and southern Idaho on 4-10 ha plots, one in each seral stage. M=meadow, A=aspen, F=fir, S=spruce. Data from Smith and MacMahon[37].

UNDERSTORY

A second point made by Willson (1974) was that the presence of a particular layer of vegetation may be quite important biologically. In western spruce-fir forests, the understory is usually in need of management, as is generally true of most coniferous forests (e. g., Dickson and Segelquist 1979). Winn (1976) found that on the North Slope of the Unita Mountains of Utah, the more diverse understories in coniferous forests supported the most diverse avian communities. Winternitz (1976) found bird species favored spruce mixed with aspen and suggested that it may be due to the increased understory.

WIND THROW AND FALLEN TREES

The amount of downed material in spruce-fir forests also influences the distribution of some species. Winn (1976) found a correlation between downed material and increased numbers of Yellow-rumped Warbler, Hermit Thrush, and Gray-headed Junco. The presence of House Wrens may be determined by the number of fallen logs (Hubbard 1965).

Forest Management Practices

FIRE CONTROL

Engelmann spruce and subalpine fir are easily killed by fire (Loope and Gruell 1973), although in some areas the mesic nature of Engelmann spruce forests are such that they seldom burn (Weaver 1974). In the Front Range of Colorado, spruce-fir forests are entirely absent from areas where fires have occurred repeatedly over the last several hundred years (Marr 1967), and centuries old spruce-fir communities are hard to find in the northern Rockies due to fire (Habeck and Mutch 1973). Since the practice of fire suppression started at the turn of the century, Engelmann spruce and subalpine fir stands have greatly increased in area at the expense of lodgepole and aspen in the Rockies (Houston 1973, Loope and Gruell 1973), and white fir has greatly increased in the Sierra Nevada (Parsons and DeBenedetti 1979). Because biological processes are usually quite slow in spruce-fir forests, frequent fires are not needed to maintain diversity and conversely fires in spruce-fir forests can have extremely long-lasting effects (Habeck and Mutch 1973). Thus, in general, fire control is good for perpetuating old-growth spruce-fir forests. In the long run, fire control has helped cavity-nesting species that depend on rotting trees (Loope and Gruell 1973).

CUTTING

In the Rocky Mountains, spruce-fir forests are presently harvested by clear-cutting, shelterwood, and selection systems and the choice of cutting method depends largely on management objectives and on resources, social, and economic values (see review by Alexander 1977). Generally, all cutting practices are detrimental (Fig. 4) to birds that forage on or in trees (Thomas et al. 1975), and clear-cutting of large tracts of spruce-fir forest can greatly disrupt the species composition (Titterington et al. 1979), population densities (Franzreb 1977), and guild structure (Franzreb and Ohmart 1978), with aerial and ground feeders being favored by harvesting. If large areas of spruce-fir must be cut, patches of old-growth forest should be left with corridors (MacClintoch et al. 1977) connecting the patches if possible. McClelland et al. (1979) recommend 50-100 acres (20-40 ha) of old forest be left for every 1000 acres (400 ha) cut.

Smaller clear-cuts are more desirable for nongame birds since small open areas will favor certain species, such as raptors (Winn 1976), American Robin, and juncos (Hubbard 1965), and will not be as detrimental to tree-using species as would be large cuts. Austin and Perry (1979) concluded that clear-cuts of less than 100 acres (40 ha), with irregular borders (to increase edge effect), probably benefit wildlife in general. Natural regeneration of spruce-fir is possible when clear-cuts are not more than 5-8 chains (about 100-180 m) in width at any point (Noble and Ronco 1978).

Shelterwood and individual selection harvesting seem to hold promise for combining elements of both open and closed forest avian species (Fig. 4), but I can find no studies of avian response to these harvesting techniques in western spruce-fir. Overstory removal logging adversely affects the nongame bird avifauna (Franzreb 1978).

ROTATIONS

economic pressures upon the forests of the United States increase, not only
r and lumber, but also for energy (Pimentel et al. 1979), the outlook for old-
pruce-fir forests may become grim. Winn (1976) stated that any management
hat speeds up the rotation of overstories eliminates avian communities assoc-
th the final successional stage. Forestry harvesting models are now appearing

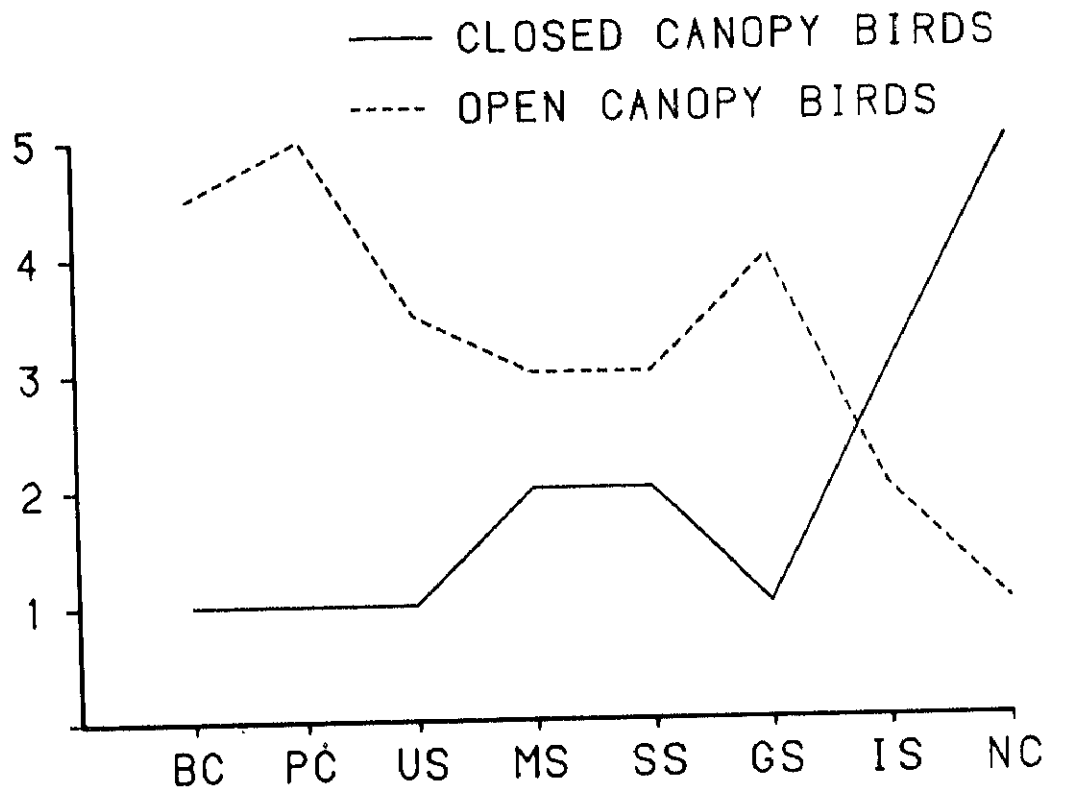


Figure 4.--Relative rankings of the effect of silvicultural systems on the open fores bird species (dotted line) and the closed forest bird species (solid line). Scale factor 1 signifies least favorable, 5 most favorable. BC=Block cutting over 10 acres, PC=Patch clear-cutting 3-5 acres, US=Uniform shelterwood, MS=Modified shelte wood, SS=Simulated shelterwood, GS=Group selection 2.0 acres, IS=Individual tree se lection, NC=No cutting. Adapted from Alexander 1977.

based on the accelerated liquidation of old-growth stands, rotations of 50 years witl an emphasis on monocultures, and the harvesting of much smaller, uniform trees (e.g. Gedney et al. 1975, Tedder 1979). These practices are obviously not compatible with the concept of relic, old-growth forests and maintenance of wildlife populations.

AERIAL SPRAYING

Very little research has been conducted in western coniferous forests on the ef fects of aerial spraying for the western budworm (Choristoneura occidentalis). DeWee et al. (1979) detected a decline in bird populations after spraying of 2 insecticide in Montana coniferous forests that contained some spruce-fir. The results were not statistically significant. They found that canopy-feeding species came in contact with the insecticides more often than other guilds, and 79% of 202 birds examined showed traces of a dye that was mixed with the insecticides.

Birds consume budworms in relation to budworm abundance, consuming large quanti ties during outbreaks and few at other times (Mook 1963). The same is true for the relationship of birds and the spruce beetle (Dendroctonus rufipennis [Kirby]), espec ially the Northern 3-toed Woodpecker (see review by Schmid and Frye[1977]).

Spraying of herbicides to remove deciduous undergrowth would also affect bird communities in spruce-fir forests. In a spruce plantation in Norway, Slagsvold (1977) found a 30% reduction in bird density the spring following application of a herbicide and the bird communities had not fully recovered 4 years later. He attributed much of the change in bird populations not only to the lack of understory, but also to a reduction in the invertebrate fauna which many species used for food.

Wildlife Management Practices

LIFE-FORM APPROACH

The life-form approach, originally applied to spruce forest birds by Haapanen (1965,1966) and recently expanded for all vertebrates of the Blue Mountains of Oregon and Washington by Thomas and his colleagues (1975,1976,1978), would seem to hold great promise for the management of western spruce-fir forests. This approach links animals to specific vegetational communities based on where the animal reproduces and forages. Due to the consistency of both the avifaunas and the guild structure from one area to another, general management objectives may be possible for vast areas of spruce-fir forests in the western states. Also, the life-form approach might be useful in identifying those species (or types of species) most dependent on old-growth spruce forests and those that would benefit from management of spruce-fir forests.

KEY SPECIES

Graul et al. (1976) suggested another technique whereby a single species (or small group of species) that is an ecological indicator of a particular ecosystem are managed for, rather than attempting to manage for all the nongame species within that ecosystem. If the species is truly an environmental indicator, then by managing for that species, the entire ecosystem will be preserved if that species is preserved. Bird populations are excellent choices as indicator species since they are quite sensitive to environmental changes (e.g., Järvinen and Väisänen 1979a). A prime candidate for the spruce-fir ecosystem would be the Northern 3-toed Woodpecker, a species found throughout the world wherever spruce occurs (Bock and Bock 1974). The Northern 3-toed Woodpecker also uses a variety of tree resources (both dead and alive) and exhibits sexual dimorphism in its foraging behavior (Hogstad 1976,1977). Although seed-eating finches and corvids are also certainly characteristic of western spruce-fir forests, it would be hard to propose specific management plans since these species have a tendency to wander widely throughout (and sometimes beyond) the spruce-fir ecosystem.

SNAG MANAGEMENT

As noted earlier, snag management is extremely important in spruce forests, and is addressed elsewhere in this volume (paper by Eileen Miller). Thomas et al. (1976) recommend that snags should be created if they do not naturally occur, a situation which may obtain in spruce forests. They point out that species can be managed at some level below maximum population size and present guidelines for such management. In spruce forests in Finland, Haapanen (1965) found fewer hole-nesters in managed forests than in a natural forest. In southern Sweden, Nilsson (1979) found hole-nesters equally as common in managed and unmanaged spruce forests.

A practice employed in northern Europe is the placement of nest boxes in forests where availability of cavities may influence breeding distribution and densities. Competition for nest holes has been documented in western forests (e.g., Franzreb 1976), but, to my knowledge, no studies have been conducted to examine the effects of supplying supplemental nest boxes in coniferous forests of the western United States.

A NORTHERN EUROPEAN EXAMPLE

In northern Europe this century, there has been a great expansion of spruce forests for harvesting. For example, in the 1920's, spruce forests comprised 28% of the forests in southern Finland. By the early 1970's, 42% of the forests were primarily spruce (Järvinen et al. 1977). Such silvicultural practices certainly have had long-term effects on the associated avifauna (e.g., Järvinen and Väisänen 1979b) and have benefitted species dependent on spruce (Haapanen 1965). In Finland bird species associated with spruce have roughly doubled in population density in the 30 years since World War II due in part to the increase in spruce (Järvinen et al. 1977); 22 of 40 species (55%) increased within the last 50 years, in part due to the increase in spruce (Järvinen and Väisänen 1978). One might thus conclude that management for spruce forests greatly benefits nongame birds, but this is not true--many species were adversely affected by spruce forest management.

In the first place, almost all species that showed an increase were common species (Järvinen et al. 1977). Not uncommonly avian densities may be high in managed spruce stands, but the number of bird species is comparatively low (e.g., Batten 1976). Second, most species dependent on old-growth stands declined. In southern Finland, there has been a 70% decrease in the number of birds which favor old forests (>140 years)(Järvinen et al. 1977). In southern Sweden, where spruce forests are intensively managed for production and not for nongame birds, Nilsson (1979) reported that bird density and number of species were 3 times lower in managed spruce and 9 times lower in young planted spruce than in naturally occurring spruce forests. He further found that with intensive management, i.e., the elimination of all deciduous elements, 5 species disappeared from the spruce forest. Haapanen (1965) found a 15-30% decrease in managed spruce avifaunas in Finland and Nilsson (1979) attributes the greater differences in Sweden to the more intense management for production in Sweden. Moss (1978a,b) documents similar declines in spruce plantations in Scotland.

CONCLUSIONS AND RECOMMENDATIONS

Two options facing forest managers concerning nongame birds in spruce-fir forests of the western United States are: manage for increased diversity or manage for old-aged stands. Managing for avian diversity would be compatible with some harvesting techniques which create openings in the forest or that open the canopy. Johnson (1975) found that habitat variety was most important in controlling the number of bird species on mountain tops in the Great Basin and Hansson (1979) has developed a model showing that landscape heterogeneity is important for the winter survival of climax conifer birds. Since little food exists in climax coniferous forests in winter, he argues that most species have to use earlier successional stages or man-made disturbances where food may be more abundant. However, managing for harvest and diversity is probably incompatible with managing for old-stand species in the same area.

Clearly, one must attempt to manage for both diversity and conservation, with the emphasis on conserving endangered or rare species, not the common and abundant species (Järvinen and Väisänen 1978). The following might be a way in which both objectives could be accomplished.

High elevation (over 3000 m) spruce-fir forests should be harvested only after much forethought has been given to the outcome and regeneration of the forest. These high elevation areas should be allowed to drift into "silvic senility" and serve as reservoirs for the spruce-fir forests that occur at lower elevations.

Lower elevation spruce-fir forests should be managed for harvesting (e.g., small clear-cuts, selection harvest), with snag management practices implemented and some deciduous elements allowed to persist. Where large areas must be harvested, patches

of old-growth forest should be left. Winn (1976) recommends that the avoidance of relic areas which represent the final stages of succession should be planned in any overall drainage sale philosophy.

Nongame bird population densities and species composition in western spruce-fir forests should be periodically estimated (i.e., every 5-10 years), and guidelines along the life-form concept should be implemented in as many areas as possible. No species intimately associated with these forests is threatened at this time, but as pressure for use of these forests increases in the near future, we must be careful that the common birds do not become even more common at the expense of the rarer species, a situation that has apparently transpired in northern Europe.

Proper snag management is important to insure that nesting cavities are available. Fire suppression in general will benefit spruce-fir avifaunas, and caution should be used with aerial spraying until more research is done in this area.

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ALPINE BIRD COMMUNITIES OF WESTERN NORTH AMERICA: IMPLICATIONS FOR MANAGEMENT AND RESEARCH[1/]

Clait E. Braun

Wildlife Researcher
Colorado Division of Wildlife, Research Center,
317 West Prospect Street, Fort Collins, Colorado 80526

ABSTRACT

The avifauna of alpine regions of western North America is notably depauperate. Average community size is normally 3 to 4 although 5 species may consistently breed and nest above treeline. Only 1 species is a year around resident and totally dependent upon alpine habitats. Seasonal habitat preferences of the breeding avifauna are identified and the complexity of the processes and factors influencing alpine regions are reviewed. Management problems are discussed and research opportunities are identified.

KEYWORDS: alpine ecosystem, habitat, avifauna, management, western North America.

INTRODUCTION

Alpine ecosystems occur in most of the high mountain cordilleras of western North America. Alpine, as used in this paper, refers to the area above treeline where habitats are characterized by short growing seasons, low temperatures and high winds. The term "tundra" is frequently used to describe these habitats but is more properly used in connection with arctic areas north of the limit of forest growth (Hoffmann and Taber 1967). While use of the terms "alpine tundra" and "arctic tundra" is common in designating above treeline (alpine) and northern lowland areas (arctic), the terminology of Billings (1979) is preferred. Likewise, lumping of alpine and arctic ecosystems into the "tundra biome" (see Kendeigh 1961) is not really feasible because of the extreme differences in radiation, moisture, topography, photoperiod, presence or absence of permafrost, etc. (Billings 1979).

Long term ecological studies of vertebrates breeding or resident in alpine ecosystems are lacking. Most studies have been done on a single species for a short

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duration (usually 1 or 2 field seasons) at a single location. During a long term study (1966 to present) of the population ecology of white-tailed ptarmigan (Lagopus leucurus)at a number of sites, opportunities were available for observations of other avian species seasonally dependent upon the alpine ecosystem. Through observation, the habitat requirements of the alpine avifauna became apparent. This paper identifies the important breeding birds of alpine habitats in western North America and their habitat preferences.

GEOGRAPHICAL DISTRIBUTION OF ALPINE HABITATS

In western North America alpine habitats occur from Alaska, Yukon Territory, British Columbia, and Alberta into the contiguous United States as far south as Arizona and New Mexico. The principal mountain ranges involved south of Canada are the Rocky Mountains on the east and the Sierra Nevada-Cascade Mountains on the west. Numerous small, isolated areas exist between these 2 great north-south systems with the east-west trending Uinta Mountains being the largest. Isolated outlying mountain ranges with small areas of alpine habitat occur east of the major cordillera in Montana and Wyoming. The 2 major mountain systems tend to merge in Canada but separate northward into Alaska.

Treeline decreases from south to north from about 3,500 meters in New Mexico, Colorado and Arizona to about 2,000 meters in northern Montana. In Alaska, treeline occurs at less than 1,000 meters. The total expanse of this area is unknown but approximately 3 million hectares of alpine habitats are estimated to occur in the contiguous western United States (Brown et al. 1978).

CHARACTERISTICS OF ALPINE HABITATS

Land Forms

The alpine landscape is rugged with steep mountains, cliffs and talus slopes being abundant. Gentle benches and slopes do occur along with many glaciated valleys originating from cirques. Frequently alpine areas are rocky, especially near morainal deposits, although large expanses of relatively smooth terrain with few apparent rocks are not uncommon. Patterned ground, rock streams and solifluction terraces caused by freezing and thawing and downslope movement of saturated soils frequently occur where moisture is sufficient. Soils on steeper slopes are shallow, weakly developed, coarse and well drained. Poorly drained bog soils occur on sites with gentle relief (Retzer 1956, Nimlos and McConnell 1962 and 1965).

Climate

The climate in alpine habitats is characterized by high winds, low temperatures, low effective moisture and short growing seasons (Marr 1961 and 1967, Judson 1977, Billings 1979). Wind is exceedingly important as it directly affects snow deposition and distribution of plant communities. Maximum wind speeds occur from November through April with occasional extremes in excess of 160 km/hr (Marr et al. 1968a and b, Judson 1977). Wind speed in summer is less with July being the calmest month (~ 10 km/hr) (Marr et al. 1968a and b).

Temperatures in alpine habitats fluctuate widely from day to day and season to season resulting in short growing seasons of up to 60 to 90 days (Billings and Mooney 1968). Some growing seasons do not exceed 45 days as night time temperatures may drop below $0^{\circ}C$ in late July and early August (Marr et al. 1968a and b). Mean daily temperatures are highest from mid-June to early September and lowest from late November into March (Marr 1961).

In alpine habitats most annual precipitation occurs in late winter and early spring (January through June) and occurs mainly as snow (Marr 1961). Fall and early winter are the driest periods and annual droughts are not uncommon. While total annual moisture may vary from 63 to 120+ centimeters (Marr et al. 1968a and b, Brown et al. 1978), not all is effective since constant winds blow much of what falls as snow from exposed areas. Some alpine habitats may be up to 70% snowfree in winter (Osburn 1963). Consequently windswept alpine habitats receive little effective moisture while more protected sites may be seasonally irrigated from melting snowfields.

Vegetation

The vegetation of alpine habitats consists mostly of perennial grasses, sedges, forbs and low growing shrubs with prominent inclusions of lichens and mosses (Billings 1979). Annuals are not common (Bliss 1971) but are somewhat more widespread in the Sierra Nevada-Cascade Mountains (Chabot and Billings 1972). Plant communities in alpine areas may be complex and extremely variable within limited distances. Moisture is a major factor affecting plant distribution with graminoids (Poaceae and Cyperaceae) and low shrubs (Salicaceae and Ericaceae) being dominant in wetter sites and cushion plants and lichens being prominent in dry sites.

Major plant communities at or above treeline vary depending upon location but can be generalized as Carex-Deschampsia meadow (Little 1941, Hanson 1953), Kobresia meadow (Marr 1961), Carex-Geum meadow, Carex-Trifolium turf, Geum turf, Salix-Carex wet meadow, cushion plant stand, Dryas stand and Krummholz (Picea-Pinus-Abies-Salix) (Daubenmire 1943, Marr 1961, and many others).

AVIFAUNA

Alpine habitats are unusually depauperate in numbers of breeding species. Typically no more than 5 species regularly complete their breeding and nesting activities above treeline. These are: white-tailed ptarmigan, horned lark (Eremophila alpestris), water pipit (Anthus spinoletta), rosy finches (Leucosticte spp.) and white-crowned sparrow (Zonotrichia leucophrys). Other species which may nest above treeline given proper circumstances are: prairie falcon (Falco mexicanus) (cliffs), common raven (Corvus corax) (cliffs), robin (Turdus migratorius) (Krummholz), and mountain bluebird (Sialia currucoides) (old buildings). Other species have been occasionally documented or suspected of nesting above treeline but these isolated occurrences are poorly documented and exceptional.

Few alpine habitats have more than 3 or rarely 4 of the 5 typical breeding species (Hoffmann and Taber 1959). Water pipits, horned larks and white-crowned sparrows are most widespread with rosy finches a close 4th. Major gaps occur in the distribution of white-tailed ptarmigan especially in the southern Cascade-Sierra Nevada Mountains and in isolated mountain ranges between the 2 major north-south cordilleras (Aldrich 1963, Braun and Rogers 1971). None of the isolated mountain ranges east of the Rocky Mountains is occupied by this grouse. In recent years successful transplants of white-tailed ptarmigan have occurred in the Sierra Nevadas (California), Wallowa Mountains (Oregon), Uinta Mountains (Utah) and Pike's Peak (Braun et al. 1978). The success of these transplants indicate that isolated alpine habitats are probably suitable for this species and that ecological barriers have been important in determining its present distribution.

Habitat Preferences

WHITE-TAILED PTARMIGAN

Habitats seasonally used by white-tailed ptarmigan in Alberta, Montana and Colorado have been described (Herzog 1977, Choate 1963, Braun 1971, Braun and Schmidt

1971, Braun et al. 1976). Winter habitats may be at or above treeline or in riparian zones some distance from alpine regions. Areas used are typically dominated by species of willows (Salix), alder (Alnus), and birch (Betula) which are used for food (Weeden 1967, May and Braun 1972) and clumps of dwarf or scattered conifers (Picea engelmannii, Abies lasiocarpa, Pinus spp.). In high snowfall areas, some use is made of aspen (Populus spp.) for winter food. Sites preferred during winter are those on the leeward sides of ridges, in cirques and drainage basins. Snow quality is important for snow roosting (Braun and Schmidt 1971) and ptarmigan may move considerable distances to suitable winter habitats (Hoffman and Braun 1975). In spring (late April-May), white-tailed ptarmigan prefer areas for breeding which became snowfree early and which are adjacent to willows. Breeding territories are selected in sites which provide both food (willows) and cover (edge of the receding snowfields). As snow melt continues, territory shape and size changes as pairs move upslope to where abundant rock cover is present (Braun 1971). Nesting usually occurs on the periphery of territories where the ground is snowfree and where cover such as bushes of willows, dwarf conifers or low rocks is available. In summer, ptarmigan prefer rocky areas (talus, fellfields, patterned ground, rock streams, etc.) which provide cover. Most sites used are adjacent to late lying snowfields or wet seeps and springs. Plants at these sites are the last to phenologically develop and the last to desiccate in late summer. Habitats selected at this time are frequently near ridge tops or permanent snowfields. In late fall (September and early October) before the 1st major winter storms, the alpine environment is exceedingly dry and most plants are desiccated. Ptarmigan distribution at this time is clumped around the few remaining snowfields or wet sites close to abundant rock cover.

HORNED LARK

While usually considered a typical resident of short grass prairies (Kelso 1931, DuBois 1935 and 1936), horned larks are seasonally resident in alpine habitats in many western mountain ranges (AOU 1957). Occurrence records of horned larks are available for most months in alpine habitats in Colorado (C. E. Braun, unpublished data) but typically they arrive in numbers above treeline in April and early May with most leaving by mid-October. Upon arriving above treeline in early spring, all but the most windswept sites are still snow covered. Territories are selected in sites dominated by cushion plants, sedges and frequently by abundant rocks. As snow melt advances, territory size increases and horned larks occupy most of the drier sites. Nests typically are in exposed areas adjacent to a small rock or tuffs of grasses or sedges. Placement of nests is usually in the lee of the sparse cover available (Pattie and Verbeek 1966, Verbeek 1967). While dry sites are preferred, Verbeek (1967) found 5 of 15 nests in moist alpine habitats. Conry (1978) observed that horned larks avoided nesting in snow accumulation areas. Foraging in spring is primarily associated with drier, windswept areas with little use of snowfields. Once hatching occurs (late May to mid-July depending upon area and year), adults noticeably forage more frequently on and along snowfields gleaning insects. This change is probably necessitated by the energy demands of nestlings (Verbeek 1967, Conry 1978). By late July, most seasonal snowfields have melted and visibility of horned larks decreases. Both adults and newly fledged young associate with habitats only recently snow free. In late summer (mid-August), flocks of horned larks use dry sites along ridges, especially fellfields and dry meadows (Verbeek 1967). Use of these habitats continues until major snowstorms occur in mid- to late October at which time most horned larks have migrated. From October until late April, the few horned larks observed in alpine habitats are associated only with windswept areas.

WATER PIPIT

This species is the most conspicuous and common breeding bird in many alpine areas (Johnson 1966, Pattie and Verbeek 1966, Verbeek 1970), occurring in most mountain

ranges of western North America (AOU 1957). It normally arrives in alpine habitats the last week of April or the 1st week of May. Upon arrival most preferred habitats are snow covered and presence of pipits above treeline is directly related to climatic conditions. During frequent spring snowstorms or when windy, pipits are absent from alpine areas and can be found on exposed slopes below treeline and in snowfree riparian habitats. With warming and receding of snowfields in mid-May, pipits establish territories in wet alpine meadows along the snowline. Foraging pipits are most frequently observed on and along snowfields from time of arrival in spring until most snow has melted. Nesting may start in late May and early June but most nest records are from late June and early July (Pattie and Verbeek 1966, Verbeek 1970, Conry 1978, C. E. Braun, unpublished data). Nests are in alpine meadows dominated by a variety of sedges (Carex, Kobresia), grasses (Poa, Deschampsia, Festuca) and forbs (Geum, Trifolium). They typically are under overhanging rocks or tufts of vegetation and are sunk into the ground (Johnson 1966, Pattie and Verbeek 1966, Verbeek 1970). Once most seasonal snowfields have melted, pipits forage in sparsely vegetated, moist habitats associated with snow accumulation sites. Flocks form in mid-August at which time pipits can be found in almost all sparsely vegetated, moist sites that remain. Numbers of pipits observed markedly decrease in late August and this species may not be seen for several days at a time. This is especially true during and immediately after early fall storms. By late September few pipits remain in alpine habitats with almost no records after the 1st week in October. Those that do remain late are normally associated with wet sites near permanent water or snow.

ROSY FINCH

The nomenclature and taxonomic relationships of rosy finches are unclear although the American Ornithologists' Union (1957) recognizes 3 species. These are: Leucosticte atrata (black rosy finch), L. australis (brown-capped rosy finch) and L. tephrocotis (gray-crowned rosy finch). Six races of L. tephrocotis have been identified (AOU 1957) but French (1959a) suggested that all present American species should be pooled into L. tephrocotis. Rosy finches are found in most of the larger mountain ranges with alpine summits in western North America but the distribution is not continuous. While racial or specific affinities may vary, habitat preference patterns are similar.

Few rosy finches occur above treeline from early November through early April. By mid- to late April small flocks of finches occur in alpine habitats foraging in windswept areas or where seed heads of grasses and sedges protrude above the snow. With warming in May, rosy finches are most frequently observed foraging on or along the edge of snowfields. This pattern continues throughout the summer until most snowfields are gone (Twining 1940, French 1959b, Johnson 1965). Numbers of finches observed in alpine habitats markedly decrease in late June as prebreeding flocks disperse and nesting is initiated. In most alpine habitats, steep cliffs are preferred for nesting (Johnson 1965) although nests in old buildings and on the ground have been reported (Hanna 1922, Cahn 1947, Kenyon 1961). Throughout the nesting period (July) and into fall, rosy finches associate with cirque headwalls, cliff faces, talus slopes, and permanent or late lying snowfields. Flocks of 30 to several hundred individuals form in late August. These flocks appear to be nomadic as they are not dependably seen. Those finches observed in late September and October are normally associated with new snowfields in areas where seed heads of Carex, Deschampsia and other grasses are abundant. By late October-early November, rosy finches are uncommon above treeline.

WHITE-CROWNED SPARROW

This species is widespread in the mountains of western North America (AOU 1957) and may be considered ecotonal as it is most abundant in the Krummholz at treeline.

However, these sparrows are seasonally resident and nest in shrub thickets (Salix, Betula, Potentilla) far above treeline. White-crowned sparrows are the latest breeding species to arrive in alpine regions, regularly appearing about mid-May. Habitats used are those dominated by shrubs, most frequently willows, and sedges. Most foraging throughout the spring, summer and fall occurs in shrub thickets, usually at ground level. Some foraging does occur on or along snowfields immediately adjacent to shrubs. Sites used for nesting are within the shrub thickets and nests may be placed in bushes or as a cup on the ground (Johnson 1966, Pattie and Verbeek 1966, C. E. Braun, unpublished data). Timing of nesting is variable depending upon area and snow conditions (Morton 1978), with most nests being found from mid-June to late July. Small aggregations of 10-15 individuals occur in shrub and Krummholz thickets after mid-August into late September. Large flocks are uncommon at any time and most white-crowned sparrows are absent from alpine habitats by early to mid-October.

MANAGEMENT OF ALPINE HABITATS

The majority of alpine areas of western North America are in public ownership controlled by United States, State, Canadian, and Provincial governments. Historically these lands have been used for grazing (Marr 1964), mining, and as a source of water. More recently recreation has become important with hiking, motorized travel, and skiing being major pastimes. The manipulation of alpine watersheds for increased downstream water flow has also increased in recent years (Marr 1964, Martinelli 1959, 1965 and 1966).

The intensity of grazing in alpine regions by domestic livestock, principally sheep, has decreased markedly (Wasser and Retzer 1966). Considerable damage to alpine habitats has been done by domestic livestock through trailing, overgrazing near permanent water sources and trampling in bedding areas (Paulsen 1960). Because of the importance of the alpine region for grazing of domestic sheep, herbicide application (2,4-D and 2,4,5-T) has been tested to reduce the abundance of alpine avens (Geum rossii), an important component of many alpine habitats (Johnson 1962, Johnson and Billings 1962). In a later study, Strasia et al. (1970) showed Geum rossii to be an important diet item of domestic sheep. Herbicide treatment (Smith and Alley 1966, Thilenius et al. 1974) almost completely eliminated alpine avens and seriously reduced the abundance of other forbs. These experiments did not consider the importance of forbs as food and cover for birds and other vertebrates even though forbs are as nutritious as grasses and sedges (Smith 1967 and 1969, Andersen and Armitage 1976). Wild ungulates also heavily graze alpine habitats and overgrazing by wapiti (Cervus elaphus), bighorn sheep (Ovis canadensis) and mountain goats (Oreamnos americanus) is not uncommon in localized areas (Thilenius 1975). Because of the grazing pressures on alpine habitats, Johnson and Smith (1966) evaluated the nutritive status of alpine soils while Bear (1978) experimented with herbicide and fertilizer application in alpine habitats. Bear found that herbicide treatments generally decreased the forb composition and herbage yield while nitrogen and phosphorous fertilizers had little effect on composition. Herbage yield was increased with phosphorous and low levels of nitrogen.

Mining historically was far more extensive but on a much smaller scale than at present. Active mines in alpine regions now tend to be large with vast disturbances of fragile habitats. Brown and Johnston (1978) estimated that nearly 12% of the alpine habitats in the western United States have been disturbed and need reclamation. The outlook is that the importance of mining in alpine regions will increase with area disturbed per mine also increasing. While interest in reclamation of disturbed alpine habitats is high (Bell and Bliss 1973, Berg et al. 1974, Zuck and Brown 1976, Brown and Johnston 1976 and 1979, Brown et al. 1978, Kenny 1978), much of the actual reclamation is too recent to be adequately evaluated. Early work by Harrington (1946) was not highly successful in revegetating road cuts along road disturbances in an alpine area of Colorado.

Recreational uses of alpine habitats vary from hiking, hunting and fishing, technical mountain climbing, camping, nature viewing to use of all terrain vehicles. While skiing is not normally important in alpine areas, some ski areas have extended lifts and trails into alpine bowls. All human uses have an impact on alpine vegetation with the greatest impacts along roads (Marr and Willard 1970, Willard and Marr 1970 and 1971). While the impacts of casual, intermittent walking in alpine areas are slight, use of all terrain vehicles such as 4 wheel drive vehicles, dune buggies, motorbikes, etc. frequently result in long term or permanent damage to alpine habitats (Ives 1974). Data on the use of snowmobiles and their effects on snow compaction, soils, wildlife and people are slowly accumulating and were reviewed by Lodico (1973). Earlier papers (Doan 1970, Schmid 1971, Neumann and Merriam 1972), indicated snowmobiles had significant, measureable impacts on snow quality and wildlife mobility and distribution.

Manipulation of alpine habitats to increase snowpack by use of snowfences and weather modification has increased in recent years with programs being operational in some areas (i.e. Colorado). While the hydrologic impacts of snowfences in alpine areas are well studied (Martinelli 1959, 1965 and 1966), impacts on vegetation and associated fauna are not. Likewise, broad studies have been conducted on the impacts of weather modification (Steinhoff and Ives 1976). Unfortunately, the impact of increased snow in alpine areas is still poorly understood.

SUMMARY AND CONCLUSIONS

This review has identified the complexity of processes and factors affecting alpine ecosystems in western North America. The avian community is small with each particular species utilizing different habitat components. Much remains to be learned about the distribution of the alpine breeding birds within western North America and reasons for the absences of some species from seemingly suitable habitats. Both the white-tailed ptarmigan and horned lark are generalists, using a variety of habitats and foods while water pipits, white-crowned sparrows and especially rosy finches are more specialized in their preferences. Because of its year around occurrence and winter dependence on low shrubs, especially willows, the white-tailed ptarmigan is especially vulnerable to disturbances of alpine habitats. Conversely this species appears to be especially adaptable to introduction into suitable unoccupied habitats in western North America. Management of alpine habitats should emphasize light grazing by domestic and wild ungulates, education of outdoor enthusiasts to the fragile nature and importance of the alpine ecosystem, total exclusion of all terrain vehicles and snowmobiles except on maintained roads, proper environmental engineering of mine sites and careful evaluation of proposed development of additional roads, water storage structures, ski facilities, electronic relay stations, and cabin sites. Important research needs include studies on the impacts of increased snowfall and snow storage on the flora and fauna, manipulation of vegetation with fertilizer and studies on the interrelationships within the avian community and the alpine ecosystem. Especially important are well designed, comparable studies on the structure and function of avian communities at a variety of sites within the alpine ecosystem of western North America.

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SPECIALIZED HABITAT NEEDS

Moderators: ROBERT K. TURNER
Rocky Mountain Region
National Audubon Society
Boulder, Colorado

NANCY G. TILGHMAN
Northeastern Forest Experiment Station
U. S. Forest Service
Amherst, Massachusetts

U.S. TIMBER NEEDS AND PROSPECTS FOR BIRD HABITATS

Norman E. Gould

Director of Timber Management
USDA Forest Service, Washington, D.C.

ABSTRACT

Western national forests will be expected to produce around 11 billion board feet of timber annually by the year 2000, an increase of 2.5 billion board feet over current annual production. Adequate assessment of the impacts of timber harvesting on nongame bird habitats in the West and evaluations of the prospects for those habitats is dependent on establishment of reasonable bird species, population, and distribution objectives supported by benefit/cost analyses, population and habitat inventories, and descriptions of the life-cycle habitat requirements of the respective species.

KEYWORDS: timber harvesting, bird habitats, bird species adaptability, bird species diversity, and bird species distribution.

Supplying the Nation's timber needs now and in the future holds the prospect for significant impacts on bird habitats, particularly in western forests. The magnitude of those impacts -- their frequency, duration, and location, and whether they can be expected to have a beneficial or detrimental effect on bird populations -- pose questions of interest to all of us.

This paper does not deal with the impacts, per se, of timber harvesting on bird habitats. Rather, it lays out, from the perspective of projected timber demands, the probable kind, location, and general distribution of harvesting and other timber management practices required to supply the timber to meet those demands.

Most of the forest lands in the West are in public ownership, largely the National Forests. Multiple-use management law and policy require consideration of the interrelationships of managing for several resources on the National Forests. Since considerable timber resource data are available for those lands, the relatively large National Forest timber management program affords

a good vista from which to look at timber production vis-á-vis bird habitats. Therefore, the material and the explanatory remarks will concentrate on National Forest management activities.

Total softwood timber demands are projected to be 73.2 billion board feet in the year 2000, assuming that the price trends from the late 1950's through the mid 1970's continue. Of the current softwood timber inventory of 1,963 billion board feet, 1,546 billion feet is in western forests, with 967 billion, or nearly two-thirds of that, on National Forest System lands.1/ To help meet our timber needs, western National Forests will be expected to produce around 11 billion board feet annually by the year 2000, an annual increase of about 2.5 billion board feet.

Immediately obvious questions arise: Where the timber will come from? Where will it be harvested or produced? How will it be produced? How will other forest resources, such as non-game birds, be affected? A partial answer to the first question is that the timber produced by the National Forest must come from a continuously shrinking base of commercial forest land. The National Forest System base decreased 5.6 million acres between 1970 and 1977 with nearly all of that decrease being in the West.2/ Note should be taken also of the fact that the timber producing base of other forest lands, particularly prime forest land, also is shrinking at a significant rate. These changes in the commercial forest land base are due primarily to changes in classification and management objectives or conversion to other uses, such as agriculture and urban development. The end result is that the Nation's timber needs will have to be supplied from a smaller timber producing land base.

Producing more timber on fewer acres translates into more intensive management for that purpose with the application of the whole array of silviculture practices necessary to maintain production at the desired levels. The prospects for bird habitats must then be considered from several standpoints: (1) the immediate areas being managed for timber production, (2) the areas not being managed for timber production, and (3) interfacing or intermingled areas. Such considerations involve a host of factors and requisite decisions that are not the subject of this paper, but they should be mentioned to keep matters in perspective. Species adaptability to changing environments and associated habitat requirements, sustainable populations, and the management objectives associated with species diversity, population, and distribution are a few of those factors and decisions requisite to determining the prospects for bird habitats as they may be affected by supplying national timber needs.

1/U.S. Department of Agriculture, Forest Service. An Assessment of the Forest and Rangeland Situation in the United States. Review RPA Draft, Washington, D.C., 556 p., 1979.

2/U.S. Department of Agriculture, Forest Service. Forest Statistics of the U.S., 1977 (Review Draft). Washington, D.C., 133 p., 1978.

The new 5-year RPA program affords an indication of the National Forest timber production activities which may have impact on bird habitats. Generally, those activities will be a complex composite of timber harvesting (logging), regeneration, and cultural treatments of varying intensities, frequencies, durations, and distribution.

Timber harvesting normally consists of regeneration and stand improvement (thinning, release, and sanitation or salvage) cutting. Of the regeneration cuts, only selection, seed tree, and shelterwood cuts involve partial cutting, and those cuts, at least the initial entries, remove trees of various sizes and ages from the timber stand. Clearcutting and group selection normally remove all the trees from areas ranging from less than an acre to several acres. Thinning, release, and sanitation or salvage cuts are all partial cuts removing dominant, co-dominant, or even understory trees from the stand. The frequency of the cuts and the number of trees removed are dependent on stand density and condition class, site productivity, silvical requirements of the tree species involved, rotation, and specific timber resource management objectives none of which can be treated as a wholly independent factor.

Within the concept of multiple use, National Forest lands have been variously classified or labeled. One of these classifications is commercial forest land. Most timber harvesting will take place on lands under this classification. It is helpful to look at the proportion of commercial to the whole of the National Forest land area.

TABLE 1.--Land classification in western National Forests.1/

Region	Commercial Forest Land	Non-commercial & Non-Forest	Deferred or Reserved	Total NFS
Northern	12,836	6,968	4,053	23,857
Rocky Mountain	10,089	7,501	2,212	19,802
South-western	5,504	14,191	772	20,467
Inter-mountain	9,500	18,826	2,650	30,976
Pacific Southwest	7,858	10,805	773	19,436
Pacific Northwest2/	20,432	19,041	3,958	43,431
TOTALS	66,219	77,332	14,418	157,969

1/Figures reflect impact of the Administration's RARE II recommendations and resource conditions as of January 1, 1980. Commercial forest land acreages differ from totals in Table 3 with earlier source data.

2/Includes Alaska (R-10).

For that portion of the National Forest System considered to be commercial forest land, we can look at the future vegetative methods. Assuming no changes in that base over the next 20 years, the approximate area to be cut over annually is estimated to be 116,000 acres of clearcutting, 578,000 acres of shelterwood and seed tree cuts, 91,000 acres of selection cutting, and 819,000 acres of intermediate and salvage cuts. Expressed in percentages of total forest land, 112,446,000 acres, this means that annually approximately 0.10 percent will be clearcut, 0.58 percent will receive shelterwood or seed tree cuts, 0.08 percent will be selection cut, and 0.73 percent will receive an intermediate or salvage cut.3/ These figures represent some significant changes from the area reported to have been cut over in 1977 - 112,000 acres of clearcutting, 457,000 acres of shelterwood and seed tree cuts, 82,000 acres of selection cutting, and 1,034,000 acres of salvage and intermediate cuts (Table 2).4/

TABLE 2.--Estimated annual area harvested by the year 2000 by Region and by cutting method. Acres reported for FY 1977 are in parentheses.

Region	METHOD OF CUTTING						Total All Methods
	Clearcut	Shelterwood: Seed Cut	Shelterwood: Prep-Removal	Selection	Inter-mediate	Salvage	
	(Thousands of Acres)						
Northern	20 (12.1)	30 (18.9)	45 (26.5)	20 (20.3)	10 (7.9)	10 (5.8)	135 (91.5)
Rocky Mtn.	7 (4.3)	25 (25.1)	50 —	— —	125 (123.7)	15 (16.8)	222 (169.9)
South-western	6 (.4)	14 (12.0)	52 (67.6)	14 (7.1)	180 (30.2)	18 (24.2)	284 (141.5)
Inter-Mtn.	10 (5.2)	9 (.9)	24 (16.2)	33 (31.9)	7 (4.5)	14 (24.9)	97 (83.6)
Pacific SW	28 (19.6)	30 (21.0)	74 (52.2)	20 (22.8)	50 (52.1)	100 (164.6)	302 (332.2)
Pacific NW	45 (70.5)	75 (63.5)	150 (153.1)	4 (.3)	40 (61.6)	250 (517.6)	564 (866.6)
Totals	116 (112.1)	183 (141.4)	395 (315.6)	91 (82.4)	412 (280.0)	407 (753.9)	1,604 (1,685.4)

'st round of land management plans for all National
will obviously have some effect on the lands classified for timber production and on local timber production goals.

As National Forest land management planning progresses under the recently established National Forest Management Act (NFMA) guidelines, a more precise determination will be made of the commercial forest land in each forest type by stand condition and productivity class. From that information, plans will be made for managing the timber resource to meet the production goals established for each National Forest, including identification of the timber stands to be harvested in each type and size class during the ensuing period(s)(Table 3). Obviously, most of the timber harvested during the next 20 or 30 years will come from regeneration cuts in the old growth and other mature stands. As all the timber producing lands are brought under management (regulation), a larger proportion of the volume harvested will come from second growth stands and intermediate cuts with a corresponding increase in the area cutover in the younger age classes.

TABLE 3.--Commercial forest land by size class in Western National Forests.

Section	Sawtimber	Poletimber	Seedlings & Saplings	Non-stocked	Total
	(Thousands of Acres)1/				
Pacific Northwest	17,833.8	2,944.1	2,087.6	462.2	23,327.7
Pacific Southwest	6,367.0	993.0	491.0	317.0	8,168.0
Northern Rocky Mt.	13,851.5	4,639.3	2,269.1	552.3	21,312.2
Southern Rocky Mt.	10,025.7	2,638.5	1,143.5	1,316.0	15,123.7
All Sections	48,078.0	11,214.9	5,991.2	2,647.5	67,931.6

1/ U.S. Department of Agriculture, Forest Service. Forest Statistics of the U.S., 1977(Review Draft). Washington, D.C.

4/All figures rounded to nearest 1000 acres. Possibility of some duplication because of definition and methods for reporting field data should not affect the overall acreage spread between methods of cutting.

Far more important, from the standpoint of bird habitats, is the need to recognize that the regulation and intensive management required to meet timber needs from this land base means sustained long-term application of a set of sequential vegetation treatments to most of the area. The only exceptions or interruptions are likely to be those occasioned by fire, windstorm, and insects or diseases and by changes in management objectives for the lands involved.

Within the set of treatments which constitute the management system for a type or stand, the regeneration cuts probably pose the single greatest potential for changing bird habitats. At the same time, the regeneration cuts usually produce the most timber per unit of area cut over, although, as indicated earlier, a larger portion of the total timber volume harvested from the National Forests will come from intermediate cuts.

Recognizing again that management objectives change and that land use planning will generate such changes or be responsive to them, it may be appropriate to make a general statement of the scope or range of regeneration cutting practices in the years to come. In the western Regions, clearcutting will be used in Englemann spruce, true firs, lodgepole pine, ponderosa pine and Douglas-fir. Shelterwood cuts will be used in Englemann spruce, ponderosa pine, Douglas-fir, and mixed conifers. Selection cutting will be used largely in stands in the special management component and some spruce-fir stands. In all Regions, local conditions and management objectives may require the use of either method of cutting in certain areas or stands.

Concurrently or following the regeneration cuts, slash treatment and site preparation treatments will be needed and applied on most if not all of the cut-over areas. Later, at intervals ranging from 3 to 5 years to intervals, in some situations, of 30 to 40 years, treatments will be needed to release crop trees from competing vegetation and to control stocking levels. These treatments will utilize a wide range of hand, mechanical, and chemical methods or practices which leave the treated material in place, as in chemical spraying and precommercial thinning, or remove all or part of it as in yarding unutilized material, commercial thinnings, and salvage or sanitation cuts.

Another point, that I believe to be critical, is that silvicultural systems can be modified or adapted to accomplish certain timber and non-timber resource (multiple use) objectives. In meeting specified management objectives however, those modifications must be compatible with the silvical and other characteristics of the tree and associated plant species. Forced modification or adaptation for a non-timber purpose may well result in unexpected and unwanted changes in the composition and condition of the plant species in the area with a concomitant change in the bird habitat.

The foregoing is a summation of supply and demand, silviculture, and multiple use consideration. These factors have been a part of planning and management for several years. Now, there is a new element about to become a part of the National Forest decisionmaking process. The National Forest Management Act, Section 6, reqires an economic evaluation of management alternatives. The law does not require selection of a management strategy that maximizes present net worth or has the highest benefit/cost ratio. It does require that in the planning process each management proposal be accompanied by a "price tag." This new economic dimension will be another factor in arriving at a selected management strategy. Intuitive decisions, if they ever were a part of forest planning, will be replaced by full disclosure of biological,

environmental, social, and economic factors. As this process relates to non-game birds, the forest planners must deal with the questions of how many, what kind, on what area, for what purpose, and at what cost.

Our management challenge is enhancement of the prospects for bird habitats on these lands without adversely affecting our ability to supply the nation's consumptive wood needs. A necessary and urgent step in this direction is establishment of bird species, population, and distribution management objectives that are reasonable and supported by good benefit/cost analyses, accurate population and habitat inventories, and description of the life-cycle habitat requirements essential to the perpetuation of the respective species. Until that is done, the impacts on western bird habitats of meeting the nation's timber needs cannot be adequately assessed.

The National Forests as public property are managed for multiple use under numerous laws and regulations. The Administration, the Congress, and the public have a large influence on our management choices. In the end, it is up to Forest Service professional resource managers to use all the available guidance and direction and make the appropriate choices between resource demands. Some of our public will prefer more boards than birds; others will desire a totally natural forest. Since God created man as a part of nature, it seems in order that we direct resource decisions to the benefit of humans. The result will be a compromise and we call this multiple use.

BIRD MANAGEMENT - EFFECTS ON TIMBER MANAGEMENT

Ted C. Stubblefield

Timber Staff Officer
USDA Forest Service, Pacific Northwest Region
Siskiyou National Forest

ABSTRACT

Proper analysis of the reciprocal effects of bird management and timber management requires a basic understanding of the individual resource complexities and acknowledgement of individual resource values. Effects should be estimated over time and on a site-specific basis to adequately reflect a most probable measure of their impact. In timber sale project planning, the timeliness of this input to the analysis process is generally critical to the quality of the end product.

The birds identified on the Threatened and Endangered Species List (U.S. Fish and Wildlife Service 1976) did not achieve that distinction solely on their own merits. The thrust of development, and in particular, associated vegetation management manipulations, bears a heavy contributing responsibility and is a very important fulcrum to retarding the growth of species extinction. The issue before us of the effects of bird management upon timber management is not so much one of not knowing what to do, as it is one of knowing when, and how to achieve it. The challenge of the wildlife biologist and the forester is a highly professional one, requiring discipline, sophistication, objectivity, determination, excellent verbal and written communication skills, and good managerial style. The failure to possess these key ingredients will most assuredly hamper successful integration of wildlife and timber resource objectives in meeting the given management objectives.

To successfully approach this subject, we need to reflect on the clarity of our direction, gain a common understanding of the timber management activities potentially affected, introspect bird management needs, and identify where best to integrate resource information and skills in recognition of effect probabilities.

Direction

American wildlife legislation, with emphasis particularly on birds, has a long history, dating back to the early part of the 1800's when the first law was passed to protect birds on a seasonal basis (Cruickshank and Cruickshank 1958). Since that time

there have been many laws designed to provide protection, enhancement, or mitigation measures for plant and animal species. A few of these laws that have been highly instrumental in redirecting resource management planning are:

National Environmental Policy Act of 1969 (NEPA)
Environmental Quality Improvement Act of 1970
Endangered Species Act of 1973
Forest and Rangeland Renewable Resources Planning Act of 1973 (RPA)
National Forest Management Act of 1976 (NFMA)
Federal Land Policy and Management Act of 1976

(U.S. Laws, Statutes, etc. 1973, and USDA Forest Service 1978)

These laws, their regulations, and agency policy that followed, all contributed in shaping our current direction in resource management. They are important to be aware of and pertinent to this subject, because from them we derive a true perspective of our situation today. As an example, NEPA requires all Federal Government agencies to "...utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment;..." (ibid). This was most likely the first legislation of its kind, directing the use of an *interdisciplinary** analysis approach in forest planning. Traditional planning techniques up to this point, commonly utilized a multidisciplinary approach in project planning. But perhaps the most important piece of legislation in forest management history is the National Forest Management Act of 1976. This statute, most commonly referred to as "NFMA," provided much new direction in many facets of resource management, with some passages being very specific concerning wildlife and timber management, as illustrated by the following:

> ...(A) *insure consideration of* the economic and environmental aspects of various systems of renewable resource management, including the related systems of silviculture and protection of forest resources, *to provide for* outdoor recreation (including wilderness), range, *timber*, watershed, *wildlife*, and fish;
>
> (B) provide for diversity of plant and animal communities based on the suitability and capability of the *specific* land area in order to meet overall multiple-use objectives,...; (NFMA, Sec. 6(g)(2)(A-B))

and in reference to even-aged management, "...such cuts are carried out in a manner consistent with the protection of soil, watershed, fish, wildlife, recreation, and esthetic resources, and the regeneration of the timber resource." (NFMA, Sec. 6(g)(2)(F)) So, by law, national forest direction to not only protect, but to provide for multiple resource values is quite clear. The challenge then in project planning is to identify resource-integrated solutions to site specific vegetation management proposals that not only address the unique resource values present, but also meet the management objectives for the area.

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*All italics used in this paper attributed to author.

Timber Management Activities

As very simply stated by David Smith (1973) concerning forest fauna, "...Anima populations are ultimately controlled by the vegetation on which they most directly or indirectly feed." Disregarding for the moment unplanned events, such as wildfires, storms, and floods, there are basically four primary activities that disturb habitat or rearrange vegetation in timber management: the application of silvicultural systems, the application of logging methods, transportation system development, and forest fuel management.

The choice of *silvicultural system*, or combination thereof, plays perhaps the most critical role in determining effects upon both bird and timber management, and, ultimately, resource yields. In the planning process, interdisciplinary team members need to be mutually cognizant of the potential degree or intensity of impact upon the various resources by alternative choices in silviculture methodology. For instance, in the choice of a *salvage* type cut in a stand, one needs to be aware that generally this implies the removal of dead or critically injured trees, as well as the utilization of sound material in down logs, unless specifically excluded by timber sale contract terminology. And in the choice of a *sanitation* cut, this can mean removal of not only dead, down, and critically injured trees, but also trees of unusually high risk due to insects or disease, or perhaps inability to sustain a net growth increment. In the use of *selection* as the method of stand treatment, the common objective is to remove mature trees, usually singly, in order to maintain a stand of many age classes indefinitely. The *shelterwood* system is the removal of mature trees in a relatively short period, in a series of cuttings, leading to natural or in combination with artificial regeneration of a new even-aged stand. With *clearcutting*, the objective is to remove the entire stand in one treatment. The latter method is prescribed for many different reasons, such as when: overall stand decadence is high; indigenous species tolerance is low; the economics of acceptable harvest methods are critical; the objective is even-aged management; it is needed to maintain commercial species site dominance; and when combinations of the above will produce other desired management results. The effect from each selected silvicultural system is not only related to the general objective of the cutting method, but perhaps more importantly, to the site-specific prescription given to a particular stand, combination of stands, or portions thereof.

In collecting information leading to the silviculture prescription, a *stand examination* is usually conducted, which often yields the following types of information: Ecoclass; site index; trees per acre; basal area per acre; potential crop trees; excess trees; percent stocking by tree class; gross volume per acre; stand age for crop trees; number of trees and gross volume per acre by DBH class, species, and tree class; average DBH by total stand and selected stand parts; individual tree characteristics record; stand decadence (general health, insect, and disease situation); and growth characteristics (stand and individuals). In addition, other data is gathered to fit the needs of the vegetation characteristics unique to the area being analyzed, and as necessary to properly prescribe stand treatment.

As appropriate as the silviculture prescription may appear, the results of the *logging method* selected may deny, or be the very mechanism that assures resource objective achievement. Through rapidly increasing technology, logging systems are available in many various potentials and economic comparisons. Ground systems include the conventional crawler tractor, the more recently developed low-ground pressure track layer, and the horse team. Perhaps the most rapidly expanding methods used in many parts of the western United States are facets of skyline logging, which are a segment of cable systems. In cable logging, many alternatives are available for consideration, such as: swing and fixed boom yarders; different

yarder strengths and capacities; multiple spar heights; carriage systems that provide lateral yarding up to several hundred feet; ground lead systems; configurations yielding one-end and full log suspension; yarding distances of several hundred feet to over one mile; intermediate slope supports, commonly referred to as a "multi-span" system; and many other options and combinations of the above methods. In aerial methods of log removal, there are: helicopters, which come in various lifting capabilities and yarding costs; balloons, which realize limited use to date, but are economically feasible; and currently on the drafting board horizon is the "helistat," which is a combination of helicopters and air-bag, producing still greater lifting capabilities. This brief encounter with logging methods is simply to provide you with a land manager's perspective of the available alternatives. It is important to recognize that a wide range of variances in systems application can be implemented in any given situation or for site-specific needs.

Intrinsic to the planning and ultimate selection of the most suitable mix of logging systems is the analysis adequacy for *transportation system development*. While many options are available in determining standards for most roading situations, the options for road location can be highly limited. Several basic roading premises need clarification. The distance from the transportation system to the total available commercial timber resource is one of the critical limiting factors in availability of logging system alternatives. Generally speaking, the greater the distance between the road and the designated timber, the fewer are the logging systems capable of removing the timber while still meeting other resource objectives. Another important concern in this relationship is that greater yarding distances most normally indicate greater costs per volume removed, need for greater cable-holding capacities, which with conventional systems[1/], means larger equipment, and in turn, that often requires slightly wider roads with somewhat less curvature. Thorough transportation analysis is synonymous with logging system analysis adequacy.

The fourth of our major vegetation rearrangement activities upon which we need to perpend is *forest fuel management*. Taken in regard to a timber sale, fuel management can be shaded fuel breaks, prescribed burning, piling and burning wood residues, chipping of slash, lopping and scattering slash, yarding unutilized material to decking sites, hazard isolation with fireline construction, felling of snags, crushing brush and slash, windrowing logging debris, debris burial, or complete removal, to name but a few of the many methods of treating forest fuels. In response to energy conservation, more and more opportunities are being pursued in fuel wood utilization, as opposed to disposal. In some parts of the country, this demand for fuel wood has more than tripled in the past few years. The term "biomass" may soon become a household word. Other considerations with fuel management, not unlike logging systems, are the instruments of achieving fuel treatment in relation to their effect. Some of these tools are: tractors, cable systems, helicopters, handwork, and combinations of these methods, each with a different cost and effect.

Bird Management Characteristics

Two excellent works that pursue wildlife habitat and their relationships with other resources to great extent are "Wildlife Habitats in Managed Forests, in the Blue Mountains of Oregon and Washington" (U.S. Department of Agriculture 1979) and a draft program on "Wildlife-Habitat Relationships" (U.S. Forest Service 1979).

[1/] The European Wyssen system is at least one exception to this.

Before delving into effects per se, let us develop a short, simplified reflection on bird characteristics and habitat needs. In the study of wildlife, particularly birds, many key terms surface, such as niche, territory, life forms, voice-printing, emphasis species, associations, cavity-nesters, diversity, edge effect, seral stage, spatial arrangement, and relationships, to name but a very few. From our earlier review of the National Forest Management Act, we know that suitable habitat diversity must be provided in forest management. From the studies mentioned above and others, we know that habitat diversity is vital to certain species' existence and their population levels; that seral stage needs by species, over time, must be determined early in planning to be effective; that certain habitat manipulations, while favoring one or more species, can be detrimental to others; that species are particularly suited to a unique niche (Hansen 1962); that species richness is generally a factor of edges; that species are highly territorial (Welty 1962); that habitat spatial arrangement (vertical, horizontal, and time) are unique needs by species; that riparian zones are one of the richest in terms of species diversity, and are of the most sensitive to alteration; that primary cavity-nesters provide much habitat for other birds as well as themselves over multi-year periods; that cavity-nesters, as a whole, play an important role in checking the natural populations of forest insects (McQuire 1979); and that such new techniques as "voiceprinting" (Wood 1979) may help us further identify not only the species present in the forest environment, but also their particular needs in terms of survival.

On the subject of primary and secondary cavity-nesters, perhaps it is best said by Lou Armijo (1979):

> "The master homebuilder of the woods is the woodpecker, whose joy, especially at mating time, is drilling neat, round holes in dead trees. .....Once a pair (of primary cavity-nesters) has selected its home, the holes left unused are free for the taking by less hard-nosed birds that cannot drill for themselves. Such species are the secondary cavity-nesters,.....or as referred to by others, the cavity-dwellers."

The aerial population of the forest can and most undoubtedly will be just as diverse as the ecosystem in which it prevails.

Effects

In analyzing the effects, or consequences, of integrated national forest bird and timber management, one must recall the direction by law and be aware of the policy as stated in the Forest Service Manual (FSM 2405.14, January 1975, Amendment 89), which states, under Wildlife and Timber Management Coordinating Instructions: "A major objective is to identify, early in the planning process, areas where the order of timber management must be tempered for wildlife habitat requirements." A great deal can happen to alter a habitat significantly, both positively and negatively, in a relatively short period of time. We will not attempt here to deal with quantitative timber yield predictions[2/] as a result of bird habitat needs, but rather examine our management activities to identify some specific areas where "effect-relationships" exist.

[2/] For an existing analysis, reference "Impacts on Wood Production," by Herbert L. Wick and Paul R. Canutt, pages 148-161 (USDA 1979).

In silvicultural practices, we might consider the following:

1. If initial stand examinations were made to be more responsive to identification of bird habitat requirements, or key indicators, unique habitat values might be more easily recognized and provided for in establishing resource objectives for a given project area. Computer assisted data sorting could facilitate key information display. The resulting effect could be protection or enhancement of threatened or emphasis species habitat by planned silviculture prescription inclusion.

2. Timber stands to be treated are often identified by silviculturists in terms of priority for increasing growth opportunities. This is particularly true of old-growth stands with a high rate of decadence. By the injection of special habitat needs for an area into this identification process, a mix of stand priorities can be analyzed in the environmental assessment to develop a set of alternatives equally responsive to all resource objectives. In other words, the area under consideration as a possible timber sale could be enlarged to include wildlife (bird) enhancement opportunities, and not necessarily to the detriment of timber objectives.

3. In developing the silviculture treatment alternatives for a given mix of stands, suitable response can be given to sensitive or critical habitats when the essential habitat information is known and integrated *early* in the planning process. The silviculture prescription can identify desirable habitat leave trees, such as for cavity-nesters, raptors, shade producers over riparian zones, roosting, foliage density maintenance for cover, and other "pre-prescription" indicated needs that meet agreed-to resource and management objectives. When this information is not timely, not factual, nor of professional quality (supportable), then the effect is that the alternatives generated for vegetation rearrangement may be unresponsive to critical wildlife needs, and a key opportunity is forgone. In draft Forest Service Manual direction (FSM 2431.2, 11/79), such information is important to be aware of several years prior to the selling of a timber sale. Preferably, this should occur before initiating the environmental analysis process, and it is highly desirable before proposing a project for the Timber Sale Program.

Let there be no misunderstanding. Critical habitat information can be vitally important to protecting a threatened or endangered species, just as can sensitive habitat for emphasis species. But the impacts to the timber resource can also be highly significant. As a simplified example, let us review a recommendation "to provide a five chain (330 feet) radius inviolate 'buffer' around a nesting site." We will also say that this proposal is on commercial forest land with a site index of 110, in Douglas-fir type, averaging 31.4 MBF per acre, with an average stumpage value of $527[3/] per MBF. The impact

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[3/] Actual calculated average during 1979 on the Siskiyou National Forest, Pacific Northwest Region, for 10 sales and 60 MMBF.

of such a recommendation on the timber resource roughly calculates out to a 7.9 acre withdrawal of approximately 248 MBF at a "stumpage value" of $130,695. This only serves to point out the potential magnitude of our recommendations. If the wildlife species is adaptable, we may have other options, such as a less intensive silviculture prescription or deferred stand selection. Computer programs are readily available to determine timber yield differences for a rotation period based on modified stand composition projections. These alternatives need careful exploration in an interdisciplinary fashion.

What might be the effects of site preparation following logging in a sensitive habitat area? Are certain fuels, or sizes of material, or blocks of cover, decayed logs or snags, needed for certain species to exist that are incapable of site adaptation? The identification of these needs, their relative values in meeting resource objectives, all need integration early in planning.

4. Commercial thinnings will most likely increase in future years to meet present timber yield predictions. What effect might this have on bird life? We must look beyond the initial timber entry to gain a true effect perspective, so that additional basal area reductions, crown cover losses, edge additions, spatial rearrangements, and ecosystem alterations are accounted for. General timber stand health will probably improve with vigor. Habitat mosaics of entire planning areas, or other areas of resource influence, need to be compiled to determine trend indicators so cumulative effects can be assessed.

5. While not related to silviculture practices alone, a very important resource opportunity now exists as a result of the National Forest Management Act (U.S. Laws, Statutes, etc. 1976, Sec. 18) which amended the Knutson-Vandenberg Act (U.S. Laws, Statutes, etc. 1930, 46 Stat. 527; 16 U.S.C. 576b) and thus provided for other than timber resource enhancement to occur. While the intent of protection and improvement of all renewable resources is quite clear, the Act specifically mentions "wildlife habitat management." The avenue for achieving this direction is via the Sale Area Improvement (S.A.I.) Plan (Forest Service Manual 2470). Where the accomplishment of one resource objective is at the partial impact of another, mitigation work can be included in the S.A.I. Plan and funds collected from timber receipts to enhance or protect other resources.

In the selection and application of logging systems, many variables can be anticipated and planned on to mitigate or create the desired effect on bird habitat. A few of the logging considerations in assessing effects are: the choice of logging system; the layout of the yarding corridors; the use of "rub trees" to minimize corridor width in cable shows; proper snag locations to meet safety requirements (USDA Forest Service 1979 b); wildlife tree protection; landing location; and the timing and duration of high noise level impacts. On national forest timber sales, special contract provisions and area restrictions can be

provided to meet required wildlife needs as determined in the environmental assessment. Restrictions on timing and duration of logging by areas is another option for sensitive species protection, such as during critical nesting or breeding periods.

The effects from a transportation development standpoint are quite different in nature. Most are permanent impacts, not temporary like silviculture and logging systems. Vegetative cover is removed and will most generally remain so. Replacement vegetation does occur on fill slopes and cut banks, and depending on the vegetation species utilized for slope stabilization, a positive food and shelter effect can be derived and planned to occur. Another "effect option" is to close system roads following their initial use, by temporarily gating or other means, thus allowing a disturbed area to "settle down" more quickly. The point of initial road alternative location analysis, early in the planning process, is a very important time for critical habitat input to occur. Opportunities generally exist during route reconnaissance to deviate or relocate to some extent, to avoid or mitigate the impact on essential wildlife habitat. And, again, timing and duration of actual construction activities is also a variable that, where essential, can be limited in the project contract.

In fuel management activities, a high degree of impact can occur which potentially can have a very positive effect or a highly negative one. We should consider the case of snags, or dead trees, briefly. Snags are known to be used for protection, communications, observation posts, roosting, nesting, food storage, and resting by many forms of wildlife. They are, without a doubt, vital to many wildlife species, both in their upright and down positions. The objective in fuel management, very basically, is to maintain fuel loading in its condition prior to an activity, or return it to a point of moderate resistance to control. It is important to recognize that this objective can be attained by many different methods, and each location, each different fuel loading situation, can be mitigated with significantly different resource impacts. It is just as important to understand that proper bird management means integration of critical input at the *beginning* of both the fuels and silvicultural analyses.

Summary

Working for the attainment of wildlife and timber resource objectives must be initiated simultaneously if they are both to be achieved with an optimal degree of success. Most ideally, these objectives should be developed, expanded, implemented, and monitored together for full realization to occur. In case it has not been made clear to this point: project environmental assessment alternatives need to be manifested in an interdisciplinary fashion to achieve optimal ecosystem management. Without such integration, there exists a tendency to be reactionary, and objective accomplishment becomes a highly difficult target. "Credibility is the currency of a professional; when it becomes devalued, so too does the profession (Glascock 1979)."

In consideration of the predicted future increased demands for goods and services, we can anticipate an increase in intensive management practices. This needs to be reconciled objectively and professionally, if it is to be achieved. There will be a gradual tendency toward younger stand age classes throughout the forest, an increase in clearcutting (although smaller in size), an increase in shelterwood cuttings, and a decrease in salvage cutting overall. The opportunities are before us and we have the tools to deal with the issues.

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CAVITY-NESTING BIRDS AND FOREST MANAGEMENT

Virgil E. Scott, Jill A. Whelan, and Peggy L. Svoboda[1]

ABSTRACT

The characteristics of dead trees (snags) used by cavity-nesting birds were examined in three timber types (aspen, ponderosa pine, and the subalpine zone). The number of snags with holes varied from less than 10 per 10 acres in the subalpine zone on the Fraser Experimental Forest in Colorado to 26 per 10 acres in ponderosa pine in Arizona. Size and species of snags used by cavity-nesting birds were examined and are discussed. Some management problems and suggestions are also discussed.

KEYWORDS: Snags, cavity-nesting birds, ponderosa pine, subalpine, aspen.

Dead trees (snags) serve a variety of purposes other than providing nest sites and dens for many cavity-nesting birds and mammals. Snags are used by raptors and fly-catching birds for hunting, feeding, loafing, and roosting. Snags are favorite loafing perches for band-tailed pigeons (Columba fasciata), and some birds and mammals use them for food storage. Bats roost under the loosened bark of dead trees, and the insects living in the dead wood provide food for several woodpecker species.

There are 85 species of cavity-nesting birds in North America (excluding Mexico) and 72 of them occur in the western United States. Cavity-nesting birds usually account for about 30 to 45 percent of the bird population in forested areas (Table 1), but can account for as much as 66 percent (Snyder 1970, 1971, 1972, 1973). Cavity-nesting birds are primarily insectivorous and may play an important role in the control of forest insect pests (Thomas et al. 1975, Massey and Wygant 1973, Bruns 1960). In addition to their economic benefits they should be considered in management practices because they are a natural part of ecosystems (Ehrenfeld 1976).

Woodpeckers (primary cavity-nesters) usually excavate new holes each year and some may excavate several holes for nesting and roosting. They usually excavate cavities in dead wood or in live trees where heart-rot (Fomes sp.) is present (McClelland and Frissel 1975). Old and unused woodpecker holes are used by other cavity-nesting birds (secondary cavity-nesters) that are unable to excavate their own holes. The secondary cavity-nesters include swallows, bluebirds, some owls,

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[1] Wildlife Research Biologist and Biological Technicians, respectively, Department of the Interior, Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado, stationed at the Fort Collins, Colorado, Field Station.

Table 1. Numbers of pairs of breeding birds/100 ac and percent cavity-nesters by timber type in the Rocky Mountain region.

Forest type	State	Number of species	Number breeding pairs	Percent cavity-nesters	Cavity-nesting species	References
Ponderosa pine	Colorado	20	96	32	6	Hering 1948
	"	13	270	44	4	Hering 1973
	Arizona	33	176	46	18	Scott 1978
	"	23	105	*45	*6	Balda 1975
	"	20	56	*42	*6	Balda 1975
	"	31	108	*32	*9	Balda 1975
Ponderosa pine-oak	Colorado	11	184	66	6	Snyder 1970, 1971, 1972, 1973
Ponderosa pine-Douglas fir	Colorado	13	102	12	2	Snyder 1950
	"	28	93	40	13	Winternitz 1976
	Montana	20	198	7	4	Manuwal 1968
Lodgepole pine	Colorado	13	59	15	1	Snyder 1950
	Wyoming	8	18	19	1	Salt 1957
	Oregon	15	125	36	4	Gashwiler 1977
Lodgepole pine with aspen	Colorado	11	65	40	4	Kingery 1970, 1971, 1973
Lodgepole pine with spruce	Wyoming	14	105	31	3	Webster 1967
Lodgepole pine-spruce-fir	Wyoming	14	49	28	4	Salt 1957
	Colorado	27	178	23	8	Scott (Fraser)
(disturbed)		25	156	21	8	
Lodgepole pine-Douglas fir (disturbed)	Montana	10	180	0	0	Frissell 1973
Lodgepole pine-larch-Douglas fir	Montana	20	184	10	3	Manuwal 1968
Pine-spruce-fir (mixed conifer)	Oregon	14	131	7	2	Archie and Hudson 1973
	Arizona	48	350	37	20	Franzreb 1977
	"	32	169	41	15	Scott 1978
Spruce-fir	Colorado	12	94	13	2	Snyder 1950
	Wyoming	19	54	17	5	Salt 1957
	Utah	23	562	24	7	Burr 1969
Aspen	Wyoming	19	523	60	5	Salt 1957
	Colorado	23	279	17	9	Scott (Stoner study)
Aspen (disturbed)		38	328	20	12	

* Secondary cavity-nesters only.

kestrels, flycatchers, wrens, and others. Chickadees and nuthatches usually use existing holes but are capable of making their own holes in very soft wood.

In recent years land managers have recognized the need for managing forest lands for nongame wildlife and have become concerned with snag management for snag-dependent wildlife. There has also been an increased interest in utilization of dead wood, as evidenced by a symposium held in Spokane, Washington, May 22-24, 1978, on "The dead softwood timber resource." This increased interest in utilization of dead wood could cause even more conflicts in snag management.

Some snag management suggestions have been made for the forests of western larch (Larix occidentalis) and Douglas-fir (Pseudotsuga menziesii) in Montana (McClelland and Frissell 1975, McClelland et al. 1979). Bull and Meslow (1977) reported on habitat requirements for the pileated woodpecker (Dryocopus pileatus) and made some management recommendations. Scott (1978) described characteristics of ponderosa pine snags used by cavity-nesters in Arizona and Scott et al. (1978) described the snags used in the subalpine zone in Colorado. In the present report we summarize the characteristics of snags used by cavity-nesting birds in three timber types: subalpine spruce-fir, ponderosa pine, and aspen.

STUDY LOCATIONS AND METHODS

Ponderosa Pine

The Rosey Creek study area is 5 miles west of Greer, Arizona, on the Apache-Sitgreaves National Forest. Elevation is about 8500 ft. At the time of our study, ponderosa pine (Pinus ponderosa) was the dominant tree species, accounting for 83 percent of the stand. Limber pine (Pinus flexilis), Douglas-fir, and quaking aspen (Populus tremuloides) made up the remaining 17 percent. All ponderosa pine snags 7 inches or greater dbh within the 124-acre study area were inventoried. Density of ponderosa pine snags averaged 4.7 snags per acre.

Subalpine Spruce-Fir

This area was in the Fraser Experimental Forest, 5 miles southwest of Fraser, Colorado. Elevation was about 10,000 ft. Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa) were the dominant tree species in valleys and on north-facing slopes; lodgepole pine (Pinus contorta) dominated southern exposures and ridges. All spruce, fir, and pine snags 4 inches dbh or greater on the two control plots (total 40 acres) and the two treatment plots (total 45 acres) were inventoried. Snag density was 17.7 snags per acre. Additional nest tree information was collected outside the study plots.

Aspen

This study area was on Stoner Mesa, 10 miles northeast of Stoner, Colorado, on the San Juan National Forest. Elevation was about 9500 ft. Quaking aspen was the dominant tree species; some ponderosa pine, Engelmann spruce, subalpine fir, and Douglas-fir were also present. All aspen snags 4 inches or greater dbh within the two control plots (total, 34.5 acres) were inventoried. Snag density averaged 13.8 snags per acre. Additional information on snags with holes was collected on areas outside these control plots.

Methods

Information collected on snags and on live trees with holes indicating bird use included: tree species, tree height, dbh, tree exposure, percentage bark retention, tree condition (live or dead), top condition (broken or intact), relative size of

branches, and condition of whitewood (rotten or solid). The presence or absence of conks on aspen snags was also noted. Other information recorded were the number of cavities present in each snag, height of the nest hole, cavity exposure, cavity type (i.e., woodpecker-made, fire scars, decayed knothole), and bird species using cavity, if known. Only those cavities that appeared to be nest holes were counted.

CHARACTERISTICS OF NEST TREES

Ponderosa Pine

Ninety-six active nest cavities of 14 species of birds were found on the ponderosa pine study area. Seventy-three were found in ponderosa pine (63 in snags, 9 in dead tops, and 1 in dead wood from lightning strike). Bird species included American kestrel (Falco sparvarius), saw-whet owl (Aegolius acadicus), common flicker (Colaptes auratus), Williamson's sapsucker (Sphyrapicus thyroideus), hairy woodpecker (Picoides villosus), northern three-toed woodpecker (Picoides tridactylus), violet-green swallow (Tachycineta thalassina), mountain chickadee (Parus gambeli), white-breasted nuthatch (Sitta carolinensis), pygmy nuthatch (Sitta pygmaea), brown creeper (Certhia familiaris), house wren (Troglodytes aedon), western bluebird (Sialia mexicana), and mountain bluebird (Sialia currucoides). Some nests of all species except hairy woodpecker and Williamson's sapsucker were found in ponderosa pine snags. Nests of additional species of birds found nesting in ponderosa pine snags off the study area were purple martin (Progne subis), and acorn woodpecker (Melanerpes formicivorus). Pygmy owls (Glaucidium gnoma), downy woodpeckers (Picoides pubescens), and western flycatchers (Empidonax difficilus) were also observed on the study area but nests were not located.

Three characteristics of ponderosa pine snags appeared important to birds in nest selection (Scott 1978): diameter of snag, percentage of bark present (table 2) and the length of time that snags had been dead. Sixty-two percent of the 424 snags dead more than 5 years had holes indicating bird use compared with 12 percent of 228 snags dead 5 years or less. Snags less than 19 inches dbh were used less frequently than larger snags (Fig. 1), and the larger snags also had more holes per snag than the smaller ones. The mean height of snags in which nests were found was 64 feet and the average dbh was 23 inches. An additional 41 ponderosa pine snags used by cavity-nesting birds off the study area averaged 61 feet tall and 23 inches dbh. Only 4 of the 114 nests were found in snags smaller than 15 inches dbh and only 23 were smaller than 18 inches dbh.

Birds made greatest use of snags that retained more than 40 percent of their bark. The bark retains moisture in the whitewood and probably improves conditions for those birds that make their own holes. Many of the holes in "hard" snags (without bark) were probably made before the bark was lost. Snags used by primary cavity-nesters averaged 90 percent bark cover (range 60 to 100) and averaged 76 percent for secondary cavity-nesters (range 20 to 100).

Subalpine Spruce-Fir

A total of 1,728 lodgepole pine, subalpine fir, and Engelmann spruce were surveyed for cavity-nesting bird use on the Fraser Experimental Forest in Colorado. The greatest bird use, as measured by the presence of excavated holes, was in dead trees with broken tops and with a dbh greater than 11 inches. In live trees, holes were usually made in dead tops or in scars.

Nests of common flickers, Williamson's sapsuckers, yellow-bellied sapsuckers (Sphyrapicus varius), and mountain chickadees were found on the study area. Other cavity-nesting birds present during the breeding season included: western flycatcher, red-breasted nuthatch (Sitta canadensis), hairy woodpecker, brown creeper,

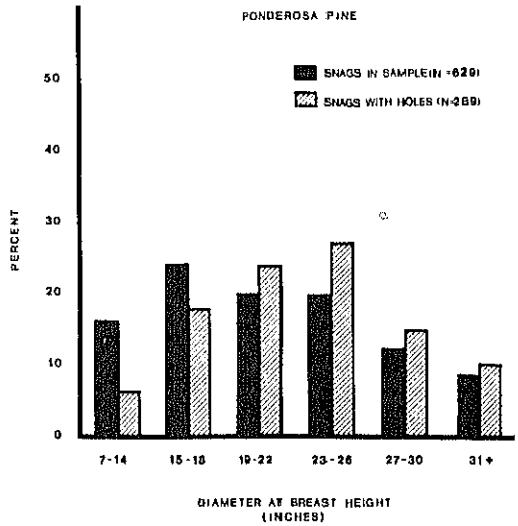

Fig. 1. Diameter distribution of ponderosa pine snags used by cavity-nesting birds when all snags were sampled within a plot.

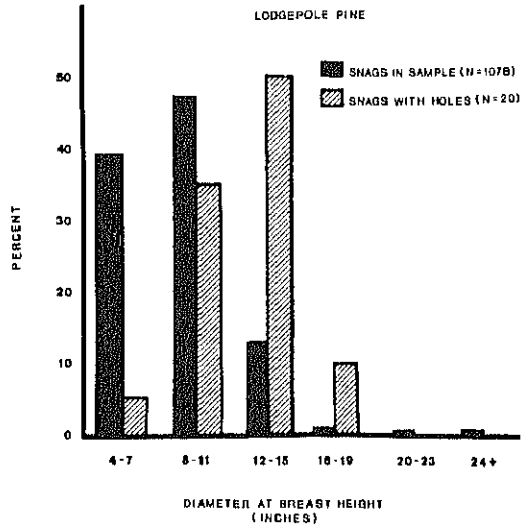

Fig. 2. Diameter distribution of lodgepole pine snags by cavity-nesting birds when all snags were sampled within a plot.

northern three-toed woodpecker, white-breasted nuthatch, black-capped chickadee (Parus atricapillus), and house wren.

Lodgepole pine snags had fewer than 1 percent use in the 4- to 11-inch diameter class, although 86 percent of the snags were in that class (Fig. 2). Eight percent of the snags with a dbh greater than 11 inches had been used. The diameter for snags used by birds averaged 13 inches (range 7-17).

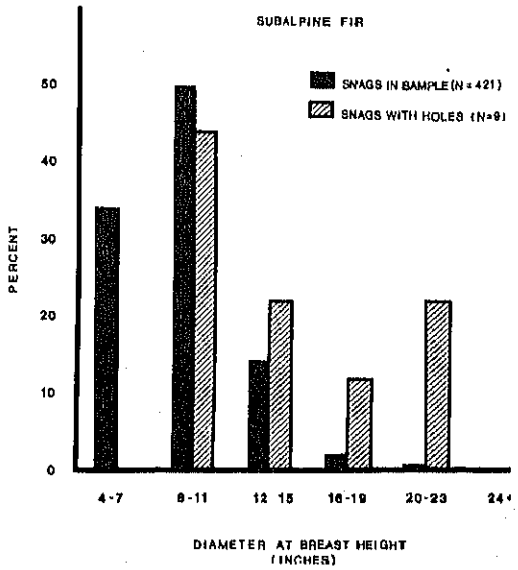

Fig. 3. Diameter distribution of subalpine fir snags used by cavity-nesting birds when all snags were sampled within a plot.

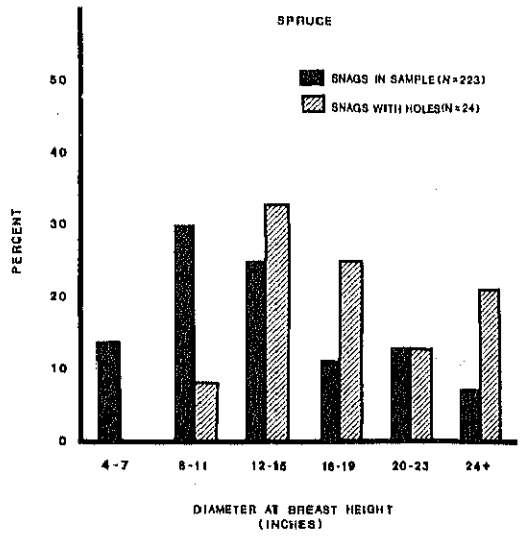

Fig. 4. Diameter distribution of Engelmann spruce snags used by cavity-nesting birds when all snags were sampled within a plot.

Table 2. Presence of nest or roost holes in ponderosa pine snags that had been dead 6 or more years by dbh size classes and percentage bark retention.

Tree size class (inches dbh)	Percent bark retention 0-20	21-40	41-60	61-80	81-100	Total
7-14						
No. examined	9	5	4	4	25	47
% with holes	22	60	25	75	32	36
Holes/used snag	1.0	2.3	3.0	2.7	3.1	2.7
15-18						
No. examined	18	10	16	14	45	103
% with holes	39	50	50	57	49	49
Holes/used snag	2.0	2.2	2.3	3.5	3.0	2.7
19-22						
No. examined	25	2	25	11	25	88
% with holes	68	100	68	91	72	73
Holes/used snag	2.4	2.0	3.3	4.4	5.2	3.7
23-26						
No. examined	23	8	31	18	9	89
% with holes	52	38	84	78	78	70
Holes/used snag	2.6	4.0	4.1	4.8	4.0	3.9
27-30						
No. examined	12	9	16	11	10	58
% with holes	58	67	88	64	80	72
Holes/used snag	3.6	5.5	4.3	5.9	6.1	5.0
31+						
No. examined	9	4	12	5	9	39
% with holes	56	100	67	60	78	69
Holes/used snag	3.6	5.5	3.0	3.0	5.1	4.0
Total						
No. examined	96	38	104	63	123	424
% with holes	52	61	71	71	57	62
Holes/used snag	2.6	3.9	3.6	4.4	4.2	3.7

The characteristics of subalpine fir snags were similar to the lodgepole. Most (84 percent) of the fir snags available were in the 4- to 11-inch dbh class (Fig. 3) and only 1 percent were used by cavity-nesters. Eight percent of the snags larger than 11 inches dbh were used, especially those snags in the 16- to 19-inch and 20- to 23-inch classes. The used fir snags averaged 14.6 inches dbh (range 10-21).

Spruce snags were generally larger than lodgepole or fir. Forty-four percent of the spruce snags were in the 4- to 11-inch diameter class (Fig. 4) and only 2 percent were used by cavity nesters. Eighteen percent of the snags larger than 11 inches dbh contained cavities. Spruce snags with holes averaged 18.6 inches (range 10.3-32.9) dbh. Spruce trees seemed to be preferred by cavity-nesters. Only 13 percent of all the snags were spruce but 43 percent of those snags with holes were spruce.

Snags with broken tops of all three tree species were used more than snags with intact tops. Used snags had broken tops in 13 of 22 lodgepole pines, 10 of 10 firs, and 17 of 24 spruce trees. Three of nine live lodgepoles and both of the live spruce trees containing cavities had broken tops.

Cavities were found in nine live lodgepole pines and two live spruce trees. All but one of the trees had a hole located either in a dead top or scar. One nest was in the live wood of a broken-top lodgepole pine. The average dbh of the live lodgepoles was 13.9 inches (range 9.3-17.3), and the live spruce diameters were 13.9 and 20.0 inches.

Aspen

A total of 104 active nests of 12 species of cavity-nesting birds were found on the aspen study area. Nests were nearly equally divided between aspen snags and live trees. The active nests were being used by the following bird species: common flicker, downy woodpecker, hairy woodpecker, house wren, mountain bluebird, mountain chickadee, purple martin, tree swallow (Iridioprocne bicolor), violet-green swallow, western bluebird, western flycatcher, and yellow-bellied sapsucker. Other cavity-nesting birds observed during breeding surveys included: black-capped chickadee, red-breasted nuthatch, white-breasted nuthatch, and brown creeper. In addition, two birds not considered cavity-nesters, hermit thrush (Catharus guttatus) and yellow-rumped warbler (Dendroica coronata), were found nesting in snags. The hermit thrush nest was in the top of a broken snag and the warbler nest was behind the loose bark of an aspen.

Snags used by cavity-nesting birds averaged 50 feet tall (range 8-85) and 16 inches dbh (range 5-25). Nearly 60 percent of the snags on the study area were in the 4- to 7-inch dbh class but less than 1 percent had holes present (Fig. 5). Generally birds selected snags and live trees larger than 11 inches dbh for nest sites. Nest heights ranged from 2 to 60 feet above ground and averaged 24.4 feet.

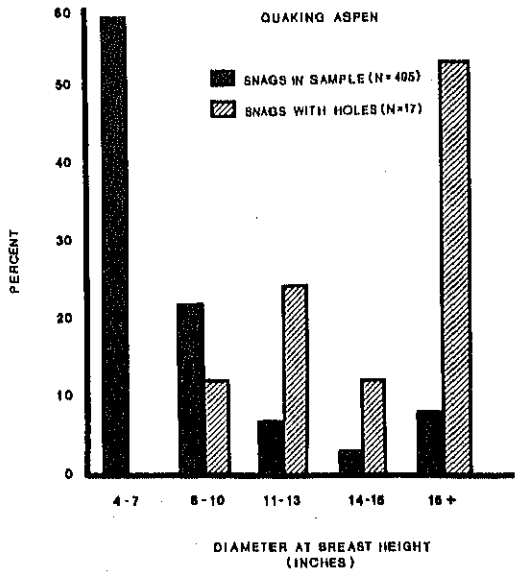

Fig. 5. Diameter distribution of quaking aspen snags used by cavity-nesting birds when all snags were sampled within a plot.

The types of cavities used included holes made by primary cavity-nesters (70 percent), holes in bark scars (mostly fire scars) (22 percent), cavities in branch knotholes (5 percent), cavities formed by loose bark (2 percent), and cavities inside the tops of broken snags (2 percent).

There was not a preference for aspen snags with broken tops as there was for lodgepole pine, spruce, and fir. Broken tops were important for the pine and fir because they permitted heart rot fungi (Fomes spp.) to enter the wood, thus softening it for use by cavity-nesting birds. Because aspen has thin bark, relatively minor wounds permit the entrance of disease organisms into the wood (Anderson et al. 1977). Apparently, broken tops are not a significant factor in themselves for selection of aspen trees by birds, but disease seemed to be an important factor. Crockett and Hadow (1975) found that in Rocky Mountain

National Park, sapsuckers were attracted to Fomes infected trees. The authors believed that the presence of shelf fungus may have provided these birds with visual cues. Fifty-two percent of the aspen snags used for cavity nests on Stoner Mesa had fruiting conks indicating the presence of heart rot but only 2 percent of the unused snags sampled had conks.

Exposure

Other characteristics of snags which were examined but not found to be significant in tree selection by cavity-nesting birds include tree height, bark retention, branch condition. We did not find that tree exposure was important in nest selection, but previous studies indicated that birds tend to choose cavities with southern exposures. Lawrence (1966), studying woodpeckers in Ontario, found that 54 percent of the cavities faced southward, 43 percent eastward, 22 percent westward, and 10 percent northward (Southward includes nests with S, SE, and SW exposures, East = E, NE, SE, etc.). In a Colorado aspen forest, Inouye (1976) found the mean orientation of flicker and sapsucker nests to be almost due south. Crockett and Hadow (1975) in Colorado and Wyoming forests, found sapsucker nest holes facing mostly south (58 percent).

At Stoner Mesa, woodpeckers selected holes nonrandomly, but the results differed from those found in the above studies. Of 14 active woodpecker nests, 50 percent faced northward, 43 percent westward, 29 percent southward, and 14 percent eastward. Fifty-one of the active secondary cavity-nesters' nests were in holes made by woodpeckers. Fifty-one percent of these nests were oriented southward, 33 percent westward, 32 percent northward, and 18 percent eastward. Woodpeckers often excavate several cavities each year before settling on one for a nest and generally excavate new holes each year. Therefore, an excess of cavities is available for secondary cavity nesters. For all excavated cavities, whether active or not, exposures were 51 percent southward, 41 percent westward, 34 percent northward, and 17 percent eastward. The orientation of cavities used by secondary cavity-nesters did not seem to vary from what was available.

In the Arizona study, active nests in both ponderosa pine and aspen showed 42 percent oriented south and 37 percent eastward. The woodpeckers chose 39 percent northward-facing holes, 35 percent southward, 35 percent westward, and 27 percent eastward. The secondary cavity-nesters' holes were mostly east and south (42 percent and 34 percent, respectively). At Manitou Springs, Colorado, most (38 percent) of the woodpeckers' nest holes faced east while most (39 percent) of the secondary cavity-nesters' holes faced south (Richard Pillmore, unpublished data).

Lawrence (1966) thought that birds preferred to excavate holes with southern exposures for maximum light and warmth. Crockett and Hadow (1965) found no significant difference in the number of eastward and westward facing holes. They suggested that warming was no more important in morning than in afternoon. They believed that nest entrance orientation is probably affected by topography and position of the nest tree relative to tree stand. The nests they observed generally faced the open edges of stands rather than the centers. Inouye (1976) found that a tendency to nest along the edges of aspen forests or the edges of clearings increased the amount of incidental solar radiation. On Stoner Mesa we found that nests often faced openings such as clearcuts, beaver ponds, or logging roads.

Paul Peterson (unpublished report) found that all the active cavity nests in oak faced either downhill or horizontally to the predominant tree exposure in Madeira Canyon, Arizona. At both Stoner Mesa and Rosey Creek, we found that 71 percent of the active nests were oriented in the direction of the tree exposure or within 90° of either side of it. We believe that there is a greater tendency for birds to locate nests f[illegible]

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Therefore, topography may be a more important factor for nest building than maximizing solar radiation.

Snag Selection by Bird Species

Nests of 289 cavity-nesting birds representing 21 species were located (Table 3). Many of the species were opportunists in locating their nests and used available nest sites. Some of the primary cavity nesters indicated a preference for tree species. On the ponderosa pine study area, where most of the snags available were ponderosa pine, Williamson's sapsuckers nested only in dead aspen or dead portions of living aspen. On the subalpine study area where aspens were not available, they nested in dead conifers.

One yellow-bellied sapsucker was found nesting in the dead portion of a live lodgepole pine but most used living aspen trees. Only two downy woodpecker nests were found and both were in dead aspen but hairy woodpeckers seemed to prefer living aspens. Flickers used both living and dead aspen and dead ponderosa pine. Flickers are probably an important primary cavity-nester in that they provide holes for secondary nesters in both conifers and deciduous trees. The flicker is also the largest of the woodpeckers in much of the Rocky Mountain area and provide holes for the larger secondary nesters such as some of the owls and kestrels.

Acorn woodpeckers are usually associated with pine-oak woodlands and provide many holes for secondary cavity-nesters. We have only recorded three nests of acorn woodpeckers and two were in ponderosa pine snags. Before we started keeping nest records, many acorn woodpeckers were observed nesting in large ponderosa pine snags on the Apache Indian Reservation in Arizona. Since they are communal nesting birds, they provide nest sites for birds like purple martins, which are also communal nesting birds. We have observed as many as 12 pairs of purple martins nesting in one ponderosa pine snag.

Secondary cavity-nesting birds are dependent on primary cavity-nesters for cavities. This group of birds is probably not tree specific but use those holes that meet certain specifications. The swallows (violet-greens, tree, and purple martins) nest in areas where they can fly to and from their nests without much obstruction. They usually nest in relatively open wooded areas or in holes that face an opening. Bluebirds like to nest near an opening or meadow, whereas pygmy nuthatches nest in the snags closely associated with other trees. Nest sites are provided for all these birds in natural conditions but must be considered in managed forests.

Management Suggestions

Snag management for cavity-nesting is complex. The density of nesting sites needed, tree species, and size of snags differ with timber type and geographic location. Needs of cavity-nesting birds vary from undisturbed old growth timber required by the spotted owl (Karalus and Eckert 1974) to rather open timber stands with openings to provide feeding areas for birds that feed in flight.

Balda (1975), Thomas et al. (1975), and Bull and Meslow (1977) have suggested methods by which the number of snags needed for cavity-nesting birds can be determined. Management for snags alone is not sufficient. Managers must be aware of the species of birds inhabiting the forest and have some knowledge of their requirements if they are to consider this unique group of birds in timber management programs. Scott (1978) found that 2.6 snags per acre had cavities made by birds in an uncut ponderosa pine forest in Arizona. In the subalpine zone of Colorado, less than one snag per acre had holes made by birds (Scott et al. 1978).

Ta ocated by bird species in three forest types and species of tree used. Means of dbh, tree height, and re also shown.

Num c nes		PONDEROSA PINE			ASPEN			OTHER		Nest height		Tree height		dbh	
		Dead	Dead top	Lightning strike	Dead	Dead top	Live	Dead	Dead top	Mean	Range (ft)	Mean	Range (ft)	Mean	Range (in)
2		1		1						45	40-50	68	55-80	28	25-30
1		1								30	---	35	---	18	---
29	ıcker	6	2		5	1	14	1		36	10-67	64	24-91	16	10-30
3	oodpecker	2			1					--	---	40	30-50	19	14-26
6	ɔellied Sapsucker						5		1	39	25-60	62	45-80	16	14-19
26	ıon's Sapsucker				18	3	1	4		25	10-60	55	24-100	14	7-33
8	.iry Woodpecker				2		6			33	22-50	59	35-70	15	10-23
2	Downy Woodpecker				2					24	21-27	45	40-50	17	16-18
2	Northern Three-toed Woodpecker	2													
1	Western Flycatcher				1					33	30-35	54	37-70	17	17-17
62	Violet-green Swallow	24	5		24	1	8			25	---	60	---	14	---
										41	7-80	64	23-120	20	5-34
									(Pine)	59	30-80	80	60-120	26	15-34
4	Tree Swallow				2		2		(Aspen)	26	7-55	51	23-80	15	5-24
23	Purple Martin	21					2			39	25-50	68	50-85	19	15-22
16	Mountain Chickadee	2			4		5	5		30	25-35	52	25-75	21	13-30
2	White-breasted Nuthatch			1	1					29	6-61	52	10-120	15	6-34
4	Red-breasted Nuthatch				3			1		31	12-50	--	---	--	---
29	Pygmy Nuthatch	27			1	1				28	14-48	53	15-85	16	7-24
5	Brown Creeper	3			1			1		43	8-80	62	30-102	23	11-37
46	House Wren	1			22		23			34	12-60	61	25-75	23	10-36
8	Western Bluebird	3	2		1		2			13	2-50	50	10-80	16	7-25
10	Mountain Bluebird	6			2		2			40	18-70	60	30-78	19	11-24
289		99	9	2	90	6	70	12	1	23	4-40	46	23-80	19	13-32

NOTE: 'OTHER' trees consist of 5 lodgepole pine, 4 Engelmann spruce, 2 white fir, 1 subalpine fir, and 1 douglas fir.

Snags eventually fall (Keen 1955) and are subject to windfall, especially in clearcut areas, and allowances must be made for snag losses in management plans. Bull and Meslow (1977) estimated that 90 sound snags greater than 20 inches dbh are needed per square mile to provide habitat for pileated woodpeckers in the Blue Mountains of Oregon. Because there is an annual loss and recruitment of snags, the number of snags needed can be calculated by their formula $S = T (L - R) + 90$ where

S = total number of snags needed per square mile
T = years to next silvicultural entry
L = annual snag loss per square mile
R = annual snag recruitment per square mile

This formula should be applicable to other areas for other birds. Many species of cavity-nesting birds will use dead portions of living trees for nesting and these can be substituted for snags. Lone trees or snags left standing alone in clearcut areas are subject to windthrow. Groups of cull trees and snags within clearcut areas would probably withstand winds better than lone trees and still provide habitat for cavity-nesting birds. Snags with broken tops were found to be important in nest selections and should be given priority when selecting snags to leave; with less wind resistance they tend to stand longer.

The number of snags used by cavity-nesting birds is usually shown as number of snags per acre. This density figure does not imply that snags should be evenly distributed over every acre. Many species of birds prefer areas near meadows or around beaver ponds and even manmade livestock watering tanks. Snags could be concentrated around such areas and fulfill the nesting requirements for cavity-nesting birds.

Increased demands for dead wood as fuel wood in recent years and utilization of dead standing trees for wood fiber has reduced the number of snags available for cavity-nesting birds in some areas. M. L. (Huck) Gaylord, Forester with Edward Hines Lumber Company, Denver, CO, estimates that in 1978, 80 million board feet or 800,000 snags were used as firewood in the Front Range of the Rockies from Denver north to the Wyoming border (pers. comm.). Some areas of national forests near metropolitan areas are now void of snags because of fuel woodcutters. Personnel from the Red Feather District of the Arapaho-Roosevelt Forest (pers. comm.) reported that about 7,000 permits were issued to fuel woodcutters on the district in 1979. They estimate that 20,000 cords of wood were cut by the permit holders. Nearly five trees 12 inches dbh and 50 feet tall are required to make a cord of wood (Forbes 1956), indicating that nearly 100,000 snags were removed from the Red Feather District in 1979.

During winter 1977-78 The Forest Service placed signs on 10 snags designating them as wildlife snags in the vicinity of Red Feather Lakes, Colorado. All 10 were cut by woodcutters by October 1979. Signs were also placed on 100 snags in the Boulder District of the Arapaho-Roosevelt National Forest in 1977 and 97 had been removed by woodcutters by fall 1979.

Snags resulting from the recent bark beetle (Dendroctonus sp.) outbreak on the Front Range of the Rocky Mountains are still present in unaccessible areas but most have been removed either by woodcutters or as salvage cuts in the more accessible areas. In areas where natural nesting sites cannot be maintained, it may be necessary to provide artificial structures. Wooden nest boxes are being put up by local groups, and bluebird trails are being established. Wooden boxes will need constant maintenance because of damage by woodpeckers, squirrels, and other rodents. If artificial structures are to be provided, they should be of more durable material than wood. Nest boxes made with a mixture of sawdust and cement have been manufactured in Germany for several years (Bruns 1960) and have proven satisfactory. They

were well accepted by birds, had better insulation against low and high temperatures, harbored fewer parasites, and were more durable than wooden boxes. Artificial nesting structures, however, should never be considered replacements for natural sites. In areas where snags have already been removed, nest boxes could help in fulfilling requirements of a group of birds that might otherwise be eliminated.

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PERPETUATING SNAGS IN MANAGED MIXED CONIFER FORESTS OF THE BLUE MOUNTAINS, OREGON

Evelyn L. Bull
Wildlife Biologist
Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, La Grande, Oregon

Asa D. Twombly
Silviculturist
Region 6, USDA Forest Service, Portland, Oregon

Thomas M. Quigley
Economist
Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, La Grande, Oregon

ABSTRACT

Both quality and quantity of snags must be considered when managing cavity nesters. Large snags with evidence of decay, existing cavities, or both are most frequently used as nest trees. To maintain woodpecker populations at 70 percent of their potential, 3.91 snags per ha (1.58 per acre) are required. Such numbers can be maintained throughout a rotation by leaving enough live trees that die or are killed to provide snags when, where, and in needed numbers.

KEYWORDS: snag, cavity nester, forest management.

INTRODUCTION

Much of National Forest Land in the Blue Mountains, although under multiple use management, is designated to be managed for timber production. Silvicultural activities influence wildlife beneficially or detrimentally depending on the species' habitat requirements.

Woodpecker populations are beneficial in two principal ways--they are insectivorous; they excavate nest and roost cavities. These cavities, when abandoned by the woodpeckers, provide nest sites for other birds and mammals (secondary cavity nesters) which require cavities for reproduction but cannot

excavate themselves. Cavity nesters exert pressure on "normal" population levels of insects thereby reducing the probability of these populations becoming epidemic (Thomas et al. 1979).

Woodpeckers generally nest in dead, standing trees (snags); foraging is more general (Lawrence 1967, Williams 1975) and includes live trees, dead and downed woody material, and snags. Therefore, management for woodpeckers involves providing snags for use as their nest trees as well as nest sites for secondary cavity nesters.

The land manager can: (1) provide no snags, (2) leave snags, or (3) construct bird boxes. Bird boxes provide habitat for only secondary cavity nesters as most woodpeckers rarely nest in them. There are types and densities of snags which best meet woodpecker needs. These conditions and the maintenance of appropriate snag densities through time are discussed below.

NEST TREE CHARACTERISTICS

Seven woodpecker species coexist in mixed coniferous forests of the Blue Mountains. Each species uses characteristic trees and forest types for nesting thereby reducing interspecific competition. The size and placement of the nest cavity determines the minimum d.b.h. (diameter at breast height) and height of suitable snags (Table 1). For example, pileated woodpeckers excavate cavities 20 cm (8 in) wide by 50 cm (20 in) deep (vertical distance), and at least 10 m (32.5 ft) above the ground. It requires a tree of at least 51-cm (20-in) d.b.h. to contain this size cavity at that height (Thomas et al. 1979).

The minimums in Table 1 are diameters of dead trees and do not include bark thickness. Not all snags meeting the minimum d.b.h. will be used as nest trees. Woodpeckers are also selective as to decay condition and nesting height. Larger snags have two advantages--more species can use the snag, and the snag will stand longer (Keen 1955, Lyon 1977, VanSickle and Benson 1978). It is best to provide snags larger than minimum size (Conner 1979).

Most woodpeckers place their nest cavities in decayed wood (Shigo and Kilham 1968, Conner et al. 1976, McClelland 1977). Miller et al. (1979) found that all woodpeckers except the pileated, which nested in sound wood 64 percent of the time, selected decayed wood for excavation. Some large snags without decay would enhance nesting opportunities for the pileated woodpecker. Woodpecker species vary in their degree of anatomical adaptation for excavation (Spring 1965). The better the adaptation, the harder the wood that can be excavated. Sapsuckers, for example, are weak excavators and select soft and decayed wood; while the pileated woodpecker is the strongest excavator (Jackman 1974) and creates cavities in sound wood.

Snags showing signs of decay are the best candidates for use as nest trees by cavity excavators. Broken-topped trees usually have decay present (McClelland and Frissell 1975). Fungal fruiting bodies (conks) also indicate decay at an advanced stage (Partridge and Miller 1974).

Snags with cavities are good candidates for nest sites. Woodpeckers will often excavate new cavities in such snags, and 53 species of secondary cavity users occupied vacated woodpecker holes in the Blue Mountains (Thomas et al. 1979).

Table 1--Snag and nest habitat characteristics of woodpeckers in mixed coniferous forests, Blue Mountains, Oregon (Thomas et al. 1979)

	Minimum d.b.h. in cm (in)	Minimum height in m (ft)	Territory size in ha (acre)	No. cavities	Snags [1] per ha (per acre)
Common Flicker *Colaptes auratus*	30.5(12)	1.8(6)	16.2(40)	1	0.93(0.38)
Pileated Woodpecker *Dryocopus pileatus*	50.8(20)	9.5(31)	121(300)	3	0.32(0.14)
Lewis' Woodpecker *Melanerpes lewis*	30.5(12)	9.1(30)	6.1(15)	1	2.49(1.01)
Williamson's Sapsucker *Sphyrapicus thyroideus*	30.5(12)	4.6(15)	4(10)	1	3.71(1.5)
Hairy Woodpecker *Picoides villosus*	25.4(10)	4.6(15)	10.1(25)	3	4.46(1.8)
White-headed Woodpecker *Picoides albolarvatus*	25.4(10)	1.8(6)	8.1(20)	3	5.58(2.25)
Black-backed Three-toed Woodpecker *Picoides arcticus*	30.5(12)	1.8(6)	30.4(75)	3	1.45(0.59)

[1] Number of snags required to meet nest tree requirements at the maximum potential woodpecker population.

Tree species selected for nest sites vary with locality, availability, tree characteristics, and decay condition. In the Blue Mountains, woodpeckers nest in ponderosa pine (*Pinus ponderosa*) snags 67 percent of the time (Fig. 1). Because of this preference and for simplicity this discussion is restricted to ponderosa pine.

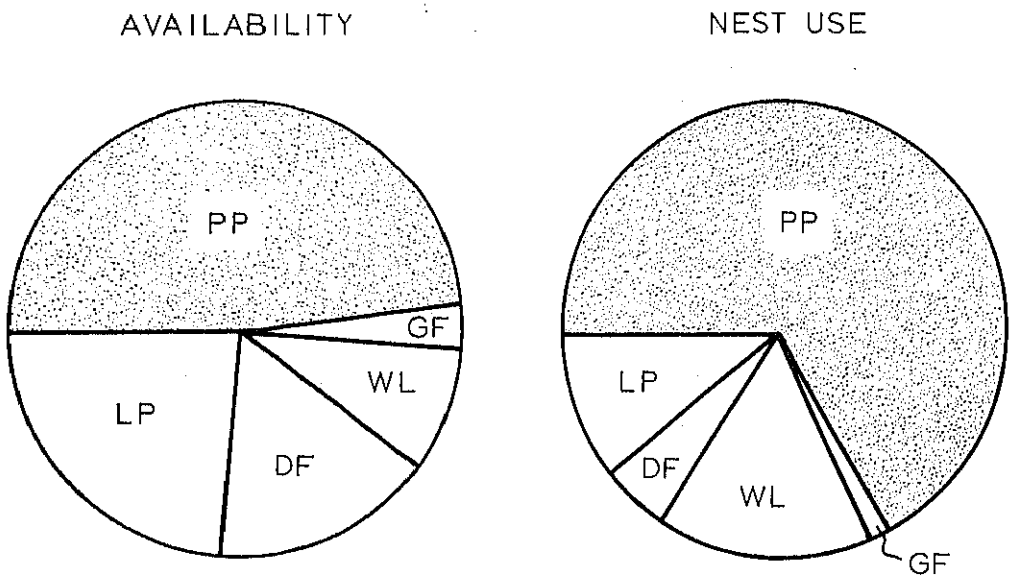

Figure 1.--Percent of available snags by tree species and percent of nest snags by species on the Starkey Experimental Forest in northeastern Oregon. PP = ponderosa pine, LP = lodgepole pine, DF = Douglas-fir, WL = western larch, GF = grand fir.

PERPETUATING DENSITIES OF SNAGS

How can appropriate size, condition, and density of snags be maintained through time? Factors affecting snag perpetuation are tree mortality rate, rate of fall of snags, and the time period.

Tree mortality varies with species and size. In the Pacific Northwest a 51-cm (20-in) d.b.h. lodgepole pine (Pinus contorta) has 10 times the probability of dying than a ponderosa pine of the same diameter. Grand fir (Abies grandis), western larch (Larix occidentalis), and Douglas-fir (Pseudotsuga menziesii) trees have slightly higher probabilities of dying than ponderosa pines (Dave Hamilton, Intermountain Forest and Range Experiment Station, Moscow, Idaho, pers. comm.).

The time a snag stands depends on cause of death, environment, tree size, species, and decay (Cline 1977). Large snags stand longer than small ones.

The period over which snags are maintained affects management. If several years are considered, few snags will fall and the management is fairly simple. In contrast, a silvicultural rotation will include several generations of snags and a more complicated management picture.

Table 2--Nest snags required per hectare by d.b.h. class at 10-percent increment levels of maximum potential woodpecker populations (Thomas et al. 1979)

Woodpecker population level (percent of potential)	Snags per ha (per acre) d.b.h. in cm (in) ≥ 25(10)	≥ 31(12)	≥ 51(20)	Total
100	1.87(0.75)	3.39(1.36)	0.32(0.14)	5.58(2.25)
90	1.69(0.68)	3.05(1.23)	0.28(0.12)	5.02(2.03)
80	1.50(0.60)	2.71(1.09)	0.25(0.11)	4.46(1.80)
70	1.32(0.53)	2.37(0.96)	0.22(0.09)	3.91(1.58)
60	1.13(0.45)	2.03(0.82)	0.19(0.08)	3.35(1.35)
50	0.94(0.38)	1.69(0.68)	0.16(0.07)	2.79(1.13)
40	0.75(0.30)	1.35(0.55)	0.13(0.05)	2.23(0.90)
30	0.56(0.23)	1.02(0.41)	0.09(0.04)	1.67(0.68)
20	0.38(0.15)	0.68(0.27)	0.06(0.03)	1.12(0.45)
10	0.19(0.08)	0.34(0.14)	0.03(0.01)	0.56(0.23)

The density of snags at any given year is a function of the initial conditions of the stand, fall rate, and the annual tree mortality. The initial stand conditions necessary include the density of live trees and snags. The functional relationship is given as:

$$S_n = (1 - F)^n S_o + (T_o)(M) \sum_{i=1}^{n} (1 - F)^{n-i} (1 - M)^{i-1}$$

Where: S_o = density of snags at year 0,
S_n = density of snags at year n,
T_o = density of trees at year 0,
n = year,
F = annual fall rate of snags, and
M = annual tree mortality.

The initial density of trees (T_o) necessary to provide, through natural mortality, the desired snag density at year n (S_n) can be determined for a stand where the tree mortality, snag fall rate, and initial snag density are known. The number of steps involved in the calculation necessitates the application of computer techniques.

This formula can be used for any area given the rate of fall of snags and tree mortality. It is essential to use data on rate of snag fall that is specific to the area and tree species being considered.

An Example

The following is a hypothetical example of how to maintain a designated snag density throughout a rotation. The manager desires to maintain 70 percent of the maximum potential population of woodpeckers (Table 2) over the entire forested area in a ponderosa pine - Douglas-fir - ninebark (Physocarpus malvaceus) plant community as described by Hall (1973). This common plant community supports seven woodpecker species. To accommodate all woodpecker species, 3.91 snags per ha (1.58 snags per acre) are required (Table 2). The minimum d.b.h. of these snags is: 1.32 snags per ha (0.53 per acre) greater than 25-cm (10-in) d.b.h., 2.37 snags per ha (0.96 per acre) greater than 31-cm (12-in) d.b.h., and 0.22 snags per ha (0.09 per acre) greater than 51-cm (20-in) d.b.h. (Table 2). For simplicity, the 25- and 31-cm d.b.h. snags are combined into one 31-cm d.b.h. class.

Managing at the 70-percent level on all forested lands all of the time throughout a rotation is just one option available to managers. It was selected in this example for the sake of simplicity. Different population levels can be managed on only a portion of an area for only a portion of a rotation. Such options give land managers more flexibility in maintaining snags than the option presented here.

The stand is mature, unmanaged, predominantly ponderosa pine overstory with a Douglas-fir understory. The stand has not been previously harvested and contains more than 3.91 snags per ha (1.58 per acre). Most mature unmanaged stands produce snags in excess of that required to support the 100-percent population level of woodpeckers, because the numbers of trees dying exceed the snags falling.

The stand is to be harvested, but 3.91 snags per ha (1.58 per acre) of the proper diameters are left along with enough live trees to replace the snags that fall, thus maintaining the 70-percent level throughout the rotation. A rotation of 130 years is planned for managed stands in public ownership.

Annual ponderosa pine mortality of trees 31-cm (12-in) and 51-cm (20-in) d.b.h. is 0.40 and 0.41 percent, respectively. Annual ingrowth within these d.b.h. categories of trees for 80 years is assumed to be 0. The rate of fall of ponderosa pine snags 25-to 51-cm (10- to 20-in) d.b.h. is 23.3 percent and of snags greater than 51-cm is 3.2 percent. These figures are the average annual percent of ponderosa pine snags used as nest trees which fell each year over a 5-year period on the Starkey Experimental Forest and Range in northeastern Oregon.

One way to maintain snags is to allow natural mortality to replace snags that fall. Because such a small percent of live trees die, a large number of

live trees must be maintained to ensure that enough snags are produced. The majority of live trees will not die and may become crop trees at some later time.

Using the formula, we find that maintaining required numbers of snags in the two diameter classes requires 291 trees per ha (117.81 per acre) greater than 31-cm (12-in) d.b.h. and 2.58 per ha (1.04 per acre) greater than 51-cm (20-in) d.b.h. to have at least 3.91 snags per ha (1.58 per acre) (70 percent level) throughout a 130-year rotation (Table 3). Snags greater than 31-cm d.b.h. need only be considered for 80 years of the rotation. At 80 years of age, a stand should have trees large enough in diameter to provide snags of the desired size and may provide them through natural mortality. Because smaller snags have a high rate of fall, more 31-cm trees are required.

Table 3--Maintaining snags over a 130-year rotation with naturally dying trees replacing snags which fall

D.b.h. in cm (in)	70% snag level snags/ha (snags/acre)	No. snags falling/ha/yr (No./acre/yr)	Percent live tree mortality	Live trees/[1] ha (/acre)
When all snags are in one diameter class:				
≥ 51(20)	3.91(1.58)	0.13(0.05)	0.41	45.77 (18.53)
When snags are in two diameter classes:				
≥ 31(12)	3.69(1.49)	0.86(0.35)	0.40	291 (117.81)
≥ 51(20)	0.22(0.09)	0.01(0.004)	0.41	2.58 (1.04)
Total	3.91(1.58)	0.87(0.354)		293.58(118.86)

[1] Number of live trees per hectare needed that will naturally die to replace snags at the 70-percent snag level throughout the 130-year rotation.

Snags greater than 51-cm d.b.h. remain standing more than seven times longer than the smaller ones. Therefore, if all snags that remain (3.91 per ha, 1.58 per acre) are at least this diameter, 45.77 live trees per ha (18.53 per acre) with mortality at the observed rate will provide the required snag level throughout the rotation.

ARTIFICIALLY CREATING SNAGS

Letting natural tree mortality replace snags which fall is the safest way of maintaining snags for nest trees. Woodpeckers use such snags. Creating snags by killing live trees may be an alternative. Although there is no proof that woodpeckers will use such snags, we see no reason why they should not.

To maintain 3.91 snags per ha (1.58 per acre) in two diameter classes for 130 years, 68.78 trees per ha (27.85 per acre) greater than 31-cm (12-in) d.b.h. and 0.92 trees per ha (0.37 per acre) greater than 51-cm (20-in) d.b.h. will be killed at a rate of 0.86 trees per ha (0.35 per acre) (≥31-cm d.b.h.) yearly for 80 years and 0.01 per ha (0.004 per acre) (≥51-cm d.b.h.) yearly for 130 years (Table 4).

Table 4--Maintaining snags over a 130-year rotation by creating snags to replace those falling

D.b.h. in cm (in)	70% snag level snags/ha (snags/acre)	Snags falling/ha/yr (No./acre/yr)	Live trees/ha[1/] (trees/acre)
When all snags are in one diameter class:			
≥ 51(20)	3.91(1.58)	0.13(0.05)	16.27(6.59)
When snags are in two diameter classes:			
≥ 31(12)	3.69(1.49)	0.86(0.35)	68.78(27.85)
≥ 51(20)	0.22(0.09)	0.01(0.004)	0.92(0.37)
Total	3.91(1.58)	0.87(0.354)	69.70(28.22)

[1/] Number of live trees/hectare needed to create snags for 130 years to maintain the 70 percent snag level.

When all snags are greater than 51-cm (20-in) d.b.h., only 16.27 live trees per ha (6.59 per acre) need to be left and killed at a rate of 0.13 per ha (0.05 per acre) yearly for 130 years.

Four methods of killing trees are being examined: topping, girdling, fungal inoculation, and silvicide treatment. It is too early to tell if woodpeckers will nest in these snags. It appears that topped trees create snags the soonest, provide an immediate entry for decay through the broken top, and are the most likely nest trees.

SILVICULTURAL SYSTEMS

number of trees required to provide snags to support a selected
on level can be achieved under either even- or uneven-aged silvicultural systems. Uneven-aged silvicultural systems exist where a selected number of trees are planned to occur over an extensive area in an array of size classes without regard to age. Number of trees decreases as size class increases. This is a difficult management system to use in western conifers as larger trees are dominant and usually grow faster than smaller trees. This continuously increases differences in diameter between the larger and smaller size classes and creates an uneven array of trees to cut or leave at harvest time.

Management of uneven-aged stands at low densities may permit the smaller or understory trees to grow at satisfactory rates with a low probability of mortality related to stress on individual trees. This system does, however, provide a wide array of tree sizes from which to create snags.

The even-aged silvicultural system consists of managing stands that have identified periods of establishment occurring after the removal of all or part of an older stand which has occupied the site. The stand has an identifiable beginning and end which establishes its age. Two-storied stand structure can be defined and produced under this system with each story having a different but relatively similar age.

Clearcut, seedtree, and shelterwood are different methods of achieving tree regeneration in the even-aged system. The "irregular shelterwood" (Hawley and Smith 1954) is a refinement of the even-aged system in which all or part of the shelter trees are retained beyond the regeneration period producing two-storied stands. The irregular shelterwood method is well suited to providing trees of a size and arrangement that can be made into snags to provide habitat for a selected density of woodpeckers. When a significant amount of shelter trees are retained, the growth rate of the established understory trees will be suppressed until released by snag creation or harvest. In appearance, it is somewhat similar to the uneven-aged system. The use of shelterwood or irregular shelterwood is generally an acceptable silvicultural treatment in the ponderosa pine or pine-associated species groups of the Blue Mountains of eastern Oregon and Washington.

The use of a clearcut method of regeneration is only partially acceptable to management for identified snag densities. A number of snags can be retained at the time of clearcutting but they will serve for only a short time. Other snag requirements must be achieved in adjacent stands which complicates the scheduling of silvicultural treatments of those units because snag numbers are more difficult to achieve over the long run.

ECONOMICS

Economics are important in decisions involving resource allocations. Snag management is no exception. Economics can help resolve several questions. Should the forest be managed to maintain snags? At what level? What are the tradeoffs among resources? What is the cost? Do the benefits outweigh costs? Which technique is least expensive?

The economist has tools available to assist in answering these questions. These include benefit/cost, present net worth, internal rate of return, least cost, and tradeoff analyses to mention a few. Most of these analyses necessitate determination of benefits in dollars. This presents problems when the resources involved are not traded in the marketplace or the price or value of the resource is not known. In such cases, two techniques which provide useful economic information are least cost and tradeoff analyses; they are briefly discussed here.

Inherent in economic analyses are assumptions. In least cost analysis, it is assumed that considered alternatives have equal or nearly equal benefits. Only costs are examined. Three categories of costs associated with snag management must be determined for least cost comparisons.

1. The costs associated with timber harvests forgone as a result of snag management must be determined. This includes the reduction in planned harvest which is a result of snag management. These reductions must be listed for the entire stand rotation, not for just the initial silvicultural treatment.

2. The costs associated with increased harvest expense due to snag management must be included. Thus, if the density of trees left is great enough to impede equipment or dictates the need for modified equipment, the costs are charged to snag management.

3. The costs associated with creating snags must also be included. These include the treatment costs as well as costs associated with planning and administering the treatments. Where snag density is provided through natural mortality these costs would be small.

The quantity and timing of costs and volume changes are important to an economic analysis. By specifying quantity changes for each year, the proper discounting factor can be applied and the present value of the costs determined. Thus, a comparison of the present value of the costs associated with each alternative can be accomplished and the least expensive alternative selected.

Tradeoff analysis can be used to demonstrate the actual changes in resource products and flows which result from alternative manangement situations. Managers can be shown the number of species which utilize an area for each alternative or the change in recreation visitor days as a result of management. These quantitative figures can be used in conjunction with the cost information described above to outline costs and impacts of management.

A technique relating these quantities with costs on a common basis (e.g., dollars) is not presently available. Research will continue into the economics of nonmarket resources and how their values can be quantified.

No comparison of timber management techniques to accomplish a given woodpecker population level will be accomplished here. As discussed, snag densities important to woodpecker population maintenance can be maintained through even- and uneven-aged timber management.

Economic comparisons still need to be made involving the methods to create snags as well as the timber management techniques employed to achieve snag densities over time.

CONCLUSIONS

Snags with known characteristics and density are essential to maintain woodpecker populations over time. In unmanaged mature stands, the number of trees dying exceeds the number of snags falling, and snag densities usually exceed those required to support the 100-percent level of woodpecker populations. In a managed stand, snags can be perpetuated by leaving trees to die or killing them. Maintaining snags to sustain a selected woodpecker population can be achieved through either even-aged or uneven-aged silvicultural systems.

Although large snags take more time to grow, they stand longer than small snags. Over a 130-year rotation, fewer live trees need to be allocated to snags if the trees left at the initial regeneration are greater than 51-cm (20-in) d.b.h.

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SNAG USE BY BIRDS

Eileen Miller

Wildlife Biologist
Box 181, Route 2
Dover, NH 03820

Donald R. Miller

Assistant Professor
INER, Univ. of N.H.
Durham, NH 03824

ABSTRACT

Primary cavity nesters select decayed places in trees for excavation. Decay incidence varies between areas and even between stands and is related to many factors both natural and man-caused. Some characteristics of nest sites used by a cavity nesting species vary with locality. These differences frequently reflect variations in decay incidence. Management plans for cavity nesters can be constructed using available information on stand and area history and decay. Creation of cavity nest trees cannot be facilitated by girdling. Size of nest trees, characteristics of decay and availability of suitable trees all affect cavity nesters. Dead and partly dead trees are important in many other ways. They are used for foraging, drumming, singing posts, food caching, nesting on, nesting under bark, hunting perches, loafing, lookouts, anvils, plucking posts, landing and roosting. Dead, dying, deformed and down trees play a vital role in a complex system.

KEYWORDS: cavity-nesting birds, decay, snags, forest management, forest residues, wildlife management, snag uses.

wood was also removed. Birds were able to locate a decayed portion in a tree even when it comprised a small percentage of the length. For example, a 28 m flat-top ponderosa pine contained a 2.6 m long decay column in the heartwood near the top where a black-backed three-toed woodpecker excavated. A 20 m lodgepole pine was sound except for a decay column of less than a meter long where a northern three-toed woodpecker excavated. In all cases the vertical part of the cavity was placed in the decay column. If the decay was on the outside working in, the cavity was in that area. If the core of the tree was decayed, surrounded by solid wood, the entrance went through solid wood and the vertical part extended down the decay column. Three nest cavities with entrances a meter or less from the ground could not have been placed any higher and still be excavated in decayed wood. Three cavities had an unusual shape which was called "wrap-around". All were in a narrow band of decay. The birds apparently excavated this shape following the decay rather than excavating in sound wood. One of these was a low nest 1 meter above ground. Another was a nest in sapwood in an old wolf Douglas-fir. Wood next to the bark was removed by the bird. This cavity and two others in decayed sapwood just fit between sound wood and bark. A tree with saprot needs to be much more extensively rotted and a larger diameter to accommodate a cavity than one which has decayed heartwood. It was concluded that except for pileated woodpeckers, the woodpecker species studied preferred to (1) excavate in decayed wood, (2) were able to locate decayed portions along the stem, (3) preferred decayed wood for excavation of the main chamber and (4) in cases where there wasn't enough decay, the bird either excavated in some sound wood or altered the shape of the nest. Decay has been frequently mentioned by many investigators in relation to cavity nesters (Bent 1964, Shigo and Kilham 1968, Dennis 1969, Ligon 1970, Kilham 1971a, McLaren 1975, Conner et al. 1976, McClelland 1977 and others).

Decay in trees is frequently referred to as saprot or heartrot. Heartrot organisms cause decay in heartwood of living trees. Entrance of organisms occurs in a number of ways such as through (1) roots, (2) wounds in the bole from fire or accidents which expose heartwood or (3) exposed heartwood in broken branches or broken tops. Exposure can be caused by insects, diseases and/or wind. Butt rots are heartrots generally confined to roots and lower parts of the bole. Trunk rots may occur anyplace in heartwood on the bole or larger branches. When a tree dies, heartrots will usually continue to spread vertically and move into sapwood. Saprot usually will not develop until the tree or branch is dead. The tree then decays from the outside in. Different species of fungi cause decay with varying characteristics such as differences in texture, rate of spread, places of entrance into trees and incidence in various locations and ecological conditions. Conks are fruiting bodies of decay fungi (Boyce 1948, Wagener and Davidson 1954).

Decay varies widely between trees of a given species, age, site quality and stand history (Browne 1956). For example, a rapid rate of decay is associated with fire wounds in the southeast while similar wounds in Maine show virtually no decay beyond wounds (Hepting and Shigo 1972). In the Lake states aspen stands older than about 40 years are subject to breakup due to *Phellinus igniarius* decay. In many other places such early breakup is rare (Anderson and Schipper 1978). Incidence in Colorado was reported lower than in Utah and higher than California (Hinds and Wengert 1977, Wagener 1963).

If we think in terms of birds using decay, reported characteristics of nest trees and placement of cavities start making sense. The high incidence of use of broken top trees (Bull 1975, Miller and Miller 1976, McClelland 1977, Raphael 1978 and others) reflects either breakage of tops because of presence of decay or broken tops providing a good entrance court for decay organisms. Lawrence (1967) and others, who did not specifically mention decay have speculated on the significance of placement of cavities under branch stubs, a conk, swollen knot or crook of the stem.

These can all be indicators of decay as are frost cracks, multiple tops, broken branches, dead tops, lightning strikes, trunk wounds--all reported as characteristics of nest trees (Miller and Miller 1976).

Variation in nest sites of a species can be seen in different localities. How much of this is a reflection of differences in decay incidence in those places which are a product of weathers, disease, fire insect and human activities?

Dennis (1969) studied flicker nesting on Nantucket Island for 11 years. In the beginning of the study pitch pine, affected by fire and the Nantucket pine tip moth (*Rhyacionia frustrana*) was well used. At that time many pitch pine trees were in later stages of decay and falling. White pine, planted 46 years before the study started, was just becoming important as a nesting site. Many trees were developing butt rot. One nest the first year of the study was the first ever reported in white pine on the island. Black oaks, mostly sprouts from old stumps with a high incidence of butt rot, were important trunk nest sites in live trees. The mean nest height in these trees was approximately 1 m. On the other hand black turpentine beetles (*Dendroctonus terebrans*) had recently caused heavy mortality in older Japanese black pine. Trunks were heavily used, apparently trees were breaking off and becoming stubs. Mean height of nests was about 2 m. In Montana (McClelland 1977) the mean height of flicker nests was 12 m. In some places a typical flicker nest is near the top of a stub which is a good place for decay to develop (Lawrence 1967). In some places this is less common.

In many areas yellow-bellied sapsuckers frequently nest in aspen infected with *Phellinus igniarius*. In Montana (McClelland 1977) the most common nest site is in western larch especially broken top live trees. McClelland found conks of *Fomitopsis officianalis* within fire scars. Twenty-nine percent of the larch nest trees showed evidence of fire. *Phellinus pini* also is an important decay organism in larch trees there.

Most woodpeckers have been reported excavating through sound sapwood (Kilham 1971a, Conner 1977 and others). Why do they seek decayed wood if they can excavate sound sapwood? Most of these birds are adapted for pecking from a vertical position which is used for food seeking and drumming. This position is also used for excavating the entrance to the cavity. Force in the blows comes from head momentum in the sapsucker, from body momentum in the black-backed three-toed woodpecker and a combination in the hairy woodpecker (Spring 1965). Excavation of the vertical chamber requires different positions. There is very little room for pecking motion when the vertical part of the cavity is started (Dennis 1964). The entrance holes of hairy woodpeckers and black-backed three-toed woodpeckers are about 4.6 cm in diameter (Miller and Miller 1976). The distance from the bill tip to the back of the head is about 7 cm. During pecking from a vertical position the distance of the bill tip from the tree before the thrust is 4-5 cm. In other words, normal pecking operations are not possible and therefore decayed wood for the vertical chamber is important.

Is a solid exterior important for a cavity? Even the boreal chickadee has been reported excavating holes where exterior wood and bark were hard (McLaren 1975). Sound wood gives more protection against predators. Raccoons have been reported ripping open nests with rotten sapwood and being unsuccessful where solid sapwood was present (Kilham 1971a). A flicker nest in a live aspen was reported ripped into by a black bear in Colorado (DeWeese and Pillmore 1972). The tree was only 25 cm d.b.h. so the nest had only a thin wall surrounding it. Large aspens containing cavities in that area frequently showed evidence of repeated climbing and scars around the nest entrance. Bear attempts and success were reported in California and Canada (Dixon 1927, Erskine and McLaren 1972). Dennis (1969) reported house

cats ripping through soft sapwood into flicker nests. Woodpeckers make entrances which fit their bodies. This size opening is easier to defend from inside (Kilham 1968). A solid exterior helps maintain nest structure and the tree is less likely to break off. Competitors for cavities have more difficulty enlarging the hole (Jackson 1978).

If most woodpeckers prefer sound sapwood and decayed heartwood, whether a tree will be a good potential nest tree is actually determined before the tree dies because that's when heartrot develops. When a tree is girdled, water continues to move up but nutrients don't move down to the roots. There are variations depending on time of year girdled, but essentially the roots cease functioning, then the water supply is cut off and the top dies also (Noel 1970). Beetle-killed (*Dendroctonus*) trees are really girdled trees. A look at reports of some of these trees can give an idea of results of girdling. Beetle-killed Douglas-fir in the Cascades decayed from the outside in. After 3 years almost two-thirds of the sapwood was decayed and decay of heartwood had begun (Wright and Harvey 1967). Beetle-killed Engelmann spruce in Utah, still standing after 25 years, was found perfectly sound except for an occasional individual with basal sapwood decay rarely higher than 0.7 m above ground. The wood became too dry for decay (Mielke 1950). Beetle-killed spruce in Colorado did show some decay. Heartrot had been present in some trees before they died. Some saprot developed. About 67 percent of windthrown trees fell because of saprots at the base or butt rots and 30 percent because of decayed roots. The greatest decay volume was from heartrots which continued to develop in dead trees (Hinds et al. 1965).

Forty percent of 670 woodpecker cavity nest trees were live (Table 1).

TABLE 1. Percent of woodpecker nests trees which were live.

Location	Reference	# of nest trees	% nest trees live
California	Raphael and White 1978[1/]	156	29
Arizona and Colorado	Scott 1980	76	43
Montana	McClelland 1977	186	53
Virginia	Conner et al. 1975	69	42
Oregon	Miller[2/]	71	27
Massachusetts	Dennis 1969	112	38
	Total	670	40

1/Avian utilization of snags in a northern California coniferous forest. Phase III. Unpublished report filed at Department of Forestry and Conservation. Univ. of Cal., Berkeley.

2/Unpublished data and/or manuscripts in preparation by Eileen Miller or Eileen Miller and Donald R. Miller.

To talk about girdling trees for cavity nesters is to miss the point. Trees are excavated because of what is going on inside them not because they are dead. They are trees with problems.

If we can assume that decay plays a large role in nest site selection, how can we use this knowledge in management plans? Several plans for calculating number of leave trees for cavity nester's present and future needs have emerged in

recent years (Thomas et al. 1976, Bull and Meslow 1977). Evans and Conner (1979) pointed out the difficulty is in determining the percent of snags in a forest that are suitable for cavity excavation. For some time now forest pathologists have been studying incidence and amount of decay in live trees by cutting up trees. The following information for some species of trees and areas is available:

mean incidence of decay at different age or diameter classes broken down to fungi species
mean volume of decay/infected tree broken down to fungi species
probability of dying
rate of fall of dead trees

With these figures it is possible to get an estimate of trees needed to produce a potential cavity tree. As trees get older, incidence of decay increases. Therefore, although some leave trees will fall with time, a higher proportion of the ones still standing will develop decay. For example predictions for aspen in Colorado (Hinds and Wengert 1977) are:

80 years	32% trees with decay
120 years	62% " " "
160 years	91% " " "

In areas where incidence of decay is high less trees need to be left and vice versa. Ground checks of stands could help with modifications for local conditions and help in the decision of whether the lower or higher range of a predictive value should be used.

In planning for nest trees certain decays would be better than others.

1. Slow-growing decays would allow the tree to last longer.
2. Trees with rapid growing saprots or butt rots would tend to fall soon.
3. Top rots would provide sites for higher nests.
4. Some decays are better for excavation and maintenance of cavity structure. For example, very crumbly or slimy decays are probably not as useful.

Other Management Considerations

DIAMETER OF TREE

Mean d.b.h. of trees used varies from place to place, however studies show that selection is for larger size trees (Gale 1973, Bull 1975, McClelland and Frissel 1975 , Miller and Miller 1976, Raphael and White 1978). Why? Some possible reasons are as follows:

A. More places to excavate
B. Older trees more likely to be decayed
C. Cavity can have thicker walls

1. tree less likely to break off at cavity (Truslow 1967)
2. thermal advantage
   a. less fluctuation of temperature (Stains 1961)
   b. easier to maintain temperature (Kendeigh 1961)

(1) Temperature regulation of nestlings isn't established for week or more (Davison and Evans 1960, Ricklefs and Hainsworth 1968).

(2) During incubation and brooding stages parent(s) stay in cavity more during cold weather (Breckenridge 1956, Lawrence 1967, Jackson 1976b). With thermal advantage of thicker walls, less time is needed to spend inside, more forage time is available.

HEIGHT OF TREE

Higher nests provide more freedom from ground predators. They are less easily found and reached. Woodpeckers and other cavity nesters will attack and dislodge predators climbing a tree. A longer expanse of bole provides more time for discovery and attack. Sometimes it takes multiple dives to dislodge or discourage a climber (Kilham 1971a, Pettingill 1976, Crockett and Hansley 1977).

When taller trees are available nest means are generally higher (Conner et al. 1975, Bull 1975, McClelland 1977). Means of heights can be deceiving. Hairy woodpeckers in Oregon tended to nest either fairly low (2-5 m) in boles of live trees or high in dead tops of live trees. Mean nesting height did not reflect a height generally used (Miller op. cit.). McClelland's (1977) 111 yellow-bellied sapsucker nest heights ranged widely with fairly equal numbers nesting at many different heights. The heights did not cluster near the mean (Evans and Conner 1979).

EFFECT OF NOT ENOUGH SUITABLE TREES

Lawrence (1967) in Ontario reported no interspecific strife between woodpeckers even when nesting very close. However, others have reported interspecific interactions which Miller and Bock (1972) suggested may reflect a lack of suitable trees. When other birds are trying to take over a cavity, parents with nestlings forage much closer to the nest and spend more time at it (Kilham 1968). Intraspecific strife also occurs and is reflected by frequent drumming into the nesting season and also by interactions. High amounts of interference from other birds appear to cause tension between members of a pair (Kilham 1959, 1962, 1966, 1973, Reller 1972, Kilham and O'Brien 1979).

Black-capped chickadees in Utah (Stefanski 1967) set up territories during their prenesting stage. Conflicts with other chickadees took up an average of 42 percent of a bird's time. If a female did not find a suitable nest site within the territory, the female selected one outside it. As a result the male would enlarge the territory to include the nest. "This encroachment caused a marked increase in frequency of territorial skirmishes between the pairs concerned."

All these factors cut into the parents' time and energy budget. Competition between cavity nesters also causes physical disruption of nests (Franzreb 1976, Zeleny 1976). If there aren't enough suitable trees, substandard trees may be used which are more susceptible to predation and other hazards. Acorn woodpeckers left the area when starlings took up all available sites (Troetschler 1976).

Possible indications of scarcity of cavities or suitable excavation trees are as follows:

A. Agressive interactions
   1. intraspecific
   2. interspecific
   3. between members of a pair
B. Reuse of same holes, same season (Miller op.cit.)
C. High percent of reuse of holes by secondary nesters the following season.
D. Unusually shaped nests

1. "wrap-around nests" mentioned earlier
2. Kilham (1971a) found an exceptionally long skinny cavity in a 12 cm aspen which was narrower and twice as long as usual. Birds didn't nest.

E. Exceptionally low nests

F. Reuse of same holes by woodpeckers the following year.
In Colorado Crockett and Hadow (1975) found reuse of 2 nests 3 years in a row by Williamson's and yellow-bellied sapsuckers. The mean d.b.h. of 40 nest trees in aspen found by them in the area was 23 cm.

OTHER USES OF SNAGS

Although information for management for cavity nest trees is accumulating, management plans for other uses of dead or partly dead trees have, in general, received much less attention.

Drumming

Drumming (loud rhythmic series of sounds produced by a woodpecker's bill hammering on a resounding object) serves various purposes especially advertisement of dominance within a territory, attraction of a mate and communication between mates (Lawrence 1967). For example pileated woodpeckers register agreement on nest location by means of drumming (Kilham 1959). Individuals show a particular preference for certain sites (Jackman 1975) which are located at strategic places in a bird's range (Lawrence 1967). Kilham (1960) reported that a female hairy woodpecker had 3 drumming trees she visited many times and 5 she used less frequently. The male used different trees.

Dead or dead-top trees with sound intact tops are frequently used, especially western larch (Bull 1975, McClelland 1977, Miller op. cit.). Sites such as half-loose bark, hollow trees and other places which reverberate loudly are also used (Kilham 1958b, Lawrence 1967). Yellow-bellied sapsuckers prefer dead pines or larch with sound short (7-25 cm) stubs on the trunk. The sound from these stubs are at different pitches (Kilham 1962, McClelland 1977, Miller op. cit.).

Roosting

Cavity nesters and some other birds spend the night in cavities or behind bark at any time of the year, use them during inclement weather and sometimes during day in good weather (Sherman 1910, Brewer 1963, Kilham 1971b, Reller 1972, Finlay 1976, Jackson 1976a). Cavities provide protection from some predators, precipitation, wind and extreme fluctuations of temperature. Less energy is required to maintain body temperature if the bird is in an enclosed space. During cold weather when food-gathering time and food may be in short supply, saving energy may mean survival (Zeleny 1976). Temperatures measured 7 cm into a vertical log in the sun on 28 Oct peaked about 1700, approximately roosting time, while temperature at 1 cm depth peaked about 1500 and cooled down much more rapidly than in at the deeper site. Most of the night there was approximately 6° C difference (Derby and Gates 1966). Balda (1975) estimated 63-73 percent of winter residents in ponderosa pine in Arizona are cavity nesters. Some cavities provide better protection than others. For example, large openings or thin walls allow more heat transfer to outside (Stains 1961). Some birds roost singly and some in groups (Frazier and Nolan 1959, Skutch 1976). They do not necessarily use the same cavity every night which may help minimize vulnerability to predators (Kilham 1971b, Pitts 1976).

Nest boxes used for roosting in winter may become traps. Bluebirds were found dead in 6 different nest boxes used as roosts in Tennessee during cold snaps two different years (Pitts 1978). Construction of nest boxes is not usually planned for holding heat (Zeleny 1976).

Many permanent resident birds roost in cavities. Roosting hole needs of resident primary cavity nesters have been built into some formulas for predicting the number of cavity trees needed (Thomas et al. 1976, Bull and Meslow 1977, Evans and Conner 1979). However migratory cavity nesters also need roost holes where they winter or wander (Skutch 1976). Migration may mean moving a considerable distance or just changing elevation (Dixon and Gilbert 1964, Bock and Lepthien 1975). Some species concentrate in winter (Kilham 1959, Koplin 1969). Has anyone built a plan to provide for roosting trees for migratory winter residents? Interest has mostly focused on the breeding population.

Some migrating birds also need roosting places. Swifts use hollow trees during migration (Skutch 1976). A large cluster (over 1 m long, 3 m wide and 3 birds deep) of migratory Vaux swifts was found roosting on a trunk. Several on the ground were dead. The exposed location apparently did not provide sufficient thermal cover. Stager (1965) commented on the increasing tendency of swifts to use chimneys. Migrating species can be easy to overlook while planning since they may be present for a very short time. Lack of suitable food and cover may be critical during migration.

Hunting Perches

A number of birds fly from a perch to catch insects in the air (flycatching or hawking) or drop from a perch to catch prey. Many but not all of these species select a dead tree or bare branch for this perch instead of a foliated one. Some examples are bluebirds, many woodpeckers, some hummingbirds, Townsend's solitaires, flycatchers such as the western wood pewee, Hammond's and olive-sided flycatcher (Jackman 1975, Verbeek 1975, MacRoberts and MacRoberts 1976, Jackson 1976b, Pinkowski 1979, Via 1979, Miller op. cit.).

Kestrels and bluebirds hunt more often by dropping from a perch, generally a dead branch, which offers a clear view and flying space. In the absence of a perch they will hunt from a hover (Cruz 1976, Pinkowski 1979, Miller op. cit.). Hovering requires a much higher expenditure of energy (King 1974). Kestrels hunting in California were successful in capturing prey 23 percent of attempts from hovers and 52 percent from perches (Collopy 1973).

Intact top western larch snags left in clearcuts were frequently used as perch sites by kestrels in Montana (McClelland 1977). Intact top whips left in clearcuts were used for hunting perches in Oregon by kestrels and Cooper's hawks (Miller op.cit).

Lookout and Loafing Perches

Many raptors use perches with a good view and open for flying as lookout and loafing perches (Hensel and Troyer 1964, Raphael and White 1978). Dead trees were preferred as daytime perches by wintering bald eagles in northwestern Washington (Stalmaster and Newman 1979). Band-tailed pigeons and mourning doves use dead limbs for perching (Scott 1978, Miller op. cit.).

Nest Material and Plucking Posts

Osprey get nest building sticks by grabbing dead branches with their feet while flying. Raptors have plucking posts.

Food Caches

Birds store or cache food which enables them to remain in an area when the food supply is low and also to stockpile rapidly when a food source is abundant and easy to obtain. Lewis' and acorn woodpeckers with nestlings cache insects during periods of high insect availability enabling them to take advantage of an insect flight. They store prey in cracks and crevices in dead branches near their flycatching perch. Several species of birds try to raid these caches (Bock 1970, MacRoberts 1970, MacRoberts and MacRoberts 1976, Miller op. cit.).

Colonies of acorn woodpeckers use large old decadent or dead prominent trees for storage. They may drill individual holes in bark for each acorn, place them in narrow deep channels in bark of old valley oaks, or in dessication cracks of dead dry limbs or trunks, or cavities. Holes are generally drilled only in dry bark or dead wood (Ritter 1938, MacRoberts and MacRoberts 1976, Gutierrez and Koenig 1978).

Cracks, crevices, loose bark, flaky bark, splintered wood, decayed wood, natural cavities, broken ends of branches, nest cavities and holes excavated during food gathering, provide places for woodpeckers and nuthatches, kestrels and other birds to store food. They frequently have to defend these stores from other birds and mammals and may re-store if caches are in danger (Ritter 1938, Kilham 1958a, 1963, 1974, Bock 1970, Constantz 1974, Balgooyen 1976, Pinkowski 1977b, Stacey and Jansma 1977, Miller op. cit.). Red-headed woodpeckers and nuthatches have been observed covering stores. They use slivers of damp wood from rotten stubs or limbs to seal-in acorns in various cavities (Kilham 1958c, 1974).

Nesting

Birds other than cavity nesters use dead trees for nesting. Johnson and Melquist (1973) concluded that the ideal nesting site for ospreys is a tall snag near water which permits an unrestricted view of the surrounding area. Snags were reported important for nesting ospreys in Oregon and Montana (Henny et al. 1978, MacCarter and MacCarter 1979).

Geese, ducks, owls, and a hermit thrush have been reported nesting on top of broken-top snags(Cowardin et al. 1967, Hornocker 1969, Forsman 1975, Thomas 1979, Scott 1980).

Brown creepers typically nest where bark has pulled away from dead or dying trees on the trunk. Some species of trees have bark which tends to be better than others. Western larch does not leave good areas for nesting and aspen tends to shred. Nests are built where cracks and holes in bark permit birds to enter and where rain is less likely to enter. The way a tree dies also influences what the bark will do (Franzreb 1977, McClelland 1977, Davis 1978). Wrens nested under loose bark which developed after a broadcast burn in a salvage cut area in which some large live grand fir and western larch had been left (Miller op. cit.). Scott (1980) reported a yellow-rumped warbler nesting behind loose bark of aspen.

Anvils

Anvils are places where a bird can wedge an acorn or other nut so it can be broken open. Relatively horizontal surfaces with a notch or crack such as broken top trees and horizontal dead branches with dessication cracks serve this purpose well. A bird has certain spots near storage places for this purpose (Ritter 1938, Kilham 1958a, Bock 1970, MacRoberts and MacRoberts 1976, Moskovits 1978).

Singing

Some species of birds sing from an exposed position usually on the top of a dead tree, dead branch or dead-top tree or at a lower position but still on a dead portion. Some examples are olive-backed thrush, lazuli bunting, Townsend's solitaire and hermit thrush (Miller op. cit.).

Landing On

Some species of birds land more frequently on dead trees or branches than on live trees. Birds recorded as landing on dead trees or branches more than 75 percent of the time in northeast Oregon included kestrels, broad-tailed hummingbirds, calliope hummingbirds, common flickers, yellow-bellied sapsuckers, hairy woodpeckers, olive-sided flycatchers, Townsend's solitaires and lazuli buntings. Mountain and western bluebirds did so more than 90 percent of the time. If there are dead trees extending above the canopy, flickers tend to land on these when moving from place to place. When Townsend's solitaires land on a live tree with 1 dead branch they will generally land on that branch. There is often another dead tree near a mountain bluebird nest tree which is used for landing before approaching the nest. It is easier to make an inconspicuous entry into a nest (Miller and Miller 1976, Miller op. cit.).

Some individual trees receive large amounts of use by a number of species. Many of these trees are dead, partly dead and/or with unusual configurations. Sometimes location is important such as the crest of a ridge (Miller and Miller 1976, Miller op.cit.).

Feeding

Woodpecker feeding sites have been recorded in many studies. Use of dead, dying and partly dead trees varies according to insect populations, seasons, species and sex of woodpeckers. Results of studies show that these trees play an important role in woodpecker foraging for insects (Koplin 1969, Stallcup 1969, Jackson 1970, Willson 1970, Kisiel 1972, Williams and Batzli 1979 and others).

Carpenter ants (*Camponotus* spp.) are fed on heavily by pileated woodpeckers. Williamson's sapsuckers feed huge numbers of them to nestlings. Carpenter ants were located in areas with large diameter logs, stumps, standing dead trees and live trees with basal wounds (Sanders 1970) in Ontario.

Shortly before and several years after dying,trees probably contain the heaviest concentration of prey.

Yellow-bellied and Williamson's sapsuckers are especially attracted for their sap-drilling activities to trees with [illegible]

Fallen Trees, Stumps and Slash

When a tree falls it is still useful. The exposed roots and disturbed ground provide nesting places for Townsend's solitaires, wrens and dark-eyed juncos. Branches and roots extending above ground provide singing posts and feeding areas for wrens, vireos, flycatchers, mountain chickadees and green-tailed towhees with overhead protection from avian predators. Upright branches are used as hunting posts by raptors, bluebirds, black phoebes and others (Orians and Willson 1964, Verbeek 1975, Miller op.cit.). Branches on or near ground provide cover for ground feeding birds while large logs and stumps provide feeding sites for woodpeckers, red-breasted nuthatches, yellow-rumped warblers and wrens (Hagar 1960, Kilham 1966, Bull 1975, Wily and Guampa 1978, McClelland 1979, Thomas 1979, Williams and Batzli 1979, Miller op. cit.). Brush piles become centers of activity especially for house wrens , Bewick's wrens and dark-eyed juncos (Franzreb 1977, Miller op. cit.). Large hollow stumps and logs are used by black and turkey vultures for nesting (Bent 1964).

Interrelations of Uses

Many uses are interrelated. For example, the combination of locations and quality of flycatching posts, storage places and nest cavities influences the time-energy budget of a Lewis' woodpecker pair. In the latter part of the nestling period parent birds can start showing signs of running out of time by ragged-looking feathers and later than normal roosting times (Miller op.cit.). Animals under stress are more vulnerable to predation, parasites and disease (Flook 1970, Ligon and Ligon 1978).

If more studies of habitat variables and behavior would include recording and and assessing dead tree, dead branch and down tree use, it should become possible to build all these uses into a management plan.

Nest Boxes - No Substitute for Snag Management

While nest boxes may alleviate a special local problem temporarily, they cannot be considered a substitute for snag management because:

1. they only partially provide for one of the many uses of snags.
2. they may be death traps in winter.
3. predators learn to look for nest boxes (Llewellyn and Webster 1960, Strange et al. 1971, McCluskey et al. 1977).
4. of high maintenance costs (Thomas 1979).
5. their shape may lead to blowfly parasitism (Pinkowski 1977a).

CONCLUSIONS

Short rotations, timber stand improvement, slash treatment, landscapers, fire control, and firewood collectors are all programming dead, dying, deformed and downed trees out of existence. With the ecosystem approach now coming into recognition, we need to recognize that these trees play an important role in a complex system. Stubbs(1977) , writing about wildlife and dying and dead trees in Great Britain, stated that "dead wood is now a scarce biological resource." We haven't reached that stage in many places but we're certainly working on it.

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APPENDIX

Common Name	Scientific Name
Turkey vulture	*Cathartes aura*
Black vulture	*Coragyps atratus*
Cooper's hawk	*Accipiter cooperii*
Bald eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
American kestrel	*Falco sparverius*
Band-tailed pigeon	*Columba fasciata*
Mourning dove	*Zenaida macroura*
Vaux's swift	*Chaetura vauxi*
Broad-tailed hummingbird	*Selasphorus platycercus*
Calliope hummingbird	*Stellula calliope*
Common flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Red-headed woodpecker	*Melanerpes erythrocephalus*
Acorn woodpecker	*Melanerpes formicivorus*
Lewis's woodpecker	*Melanerpes lewis*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Hairy woodpecker	*Picoides villosus*
Black-backed three-toed woodpecker	*Picoides arcticus*
Northern three-toed woodpecker	
Black phoebe	
Hammond's flycatcher	
Western wood pewee	
Olive-sided flycatcher	
Black-capped chickadee	
Mountain chickadee	
Boreal chickadee	
White-breasted nuthatch	
Red-breasted nuthatch	
Brown creeper	
House wren	
Bewick's wren	
Hermit thrush	
Olive-backed thrush	
Western bluebird	
Mountain bluebird	
Townsend's solitaire	

Starling	*Sturnus vulgaris*
Yellow-rumped warbler	*Dendroica coronata*
Lazuli bunting	*Passerina amoena*
Green-tailed towhee	*Pipilo chlorurus*
Dark-eyed junco	*Junco hyemalis*
Raccoon	*Procyon lotor*
Black bear	*Ursus americanus*
Engelmann spruce	*Picea engelmannii*
Western larch	*Larix occidentalis*
Ponderosa pine	*Pinus ponderosa*
Lodgepole pine	*Pinus contorta*
White pine	*Pinus strobus*
Pitch pine	*Pinus rigida*
Japanese black pine	*Pinus thunbergii*
Douglas-fir	*Pseudotsuga menziesii*
Aspen	*Populus tremuloides*
Valley oak	*Quercus lobata*
Black oak	*Quercus velutina*
Grand fir	*Abies grandis*

ASSEMBLAGES OF BIRD SPECIES IN WESTERN CONIFEROUS OLD-GROWTH FORESTS[1/]

R. William Mannan

Cooperative Wildlife Research Unit
Oregon State University
Corvallis, Oregon 97331

ABSTRACT

A review of available literature revealed that bird species richness and total bird density varied considerably among assemblages of bird species in various forest types of old-growth timber. However, proportions of species and individuals in foraging and nesting guilds were similar. Among foraging guilds, the number of species and individuals in the "tree-foliage-searching" and "ground-brush-foraging" categories were most abundant. Among nesting guilds, coniferous-tree-nesting birds and hole-nesting birds comprised the greatest proportions of species and individuals. Changes in vegetation structure caused by timber management have a tremendous potential impact on assemblages of bird species. One change that may have a particularly strong impact is the elimination of older forest age classes. Several bird species appear to be negatively impacted by the reduction of old-growth forests. Effects of altering natural assemblages of bird species upon forest systems are unknown, but it is conjectured that a reduction in the number of insectivorous birds may result in reduced stability. Management for high species richness or diversity, with little regard for natural species composition is questioned. Intensive efforts directed at gaining information on wildlife in old-growth forests are advocated.

KEY WORDS: birds, western coniferous forests, old-growth forests, timber management, hole-nesting birds.

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The primary goal of forest management on much of the commercial forest land in the western United States, particularly in the Pacific Northwest, is to maintain a high yield of timber. Although rotation schedules and harvest techniques vary among areas, current silvicultural practices employed to attain this goal often include (1) seeding or planting of one or a few preferred timber species following harvest, (2) precommercial and commercial thinnings to maintain high growth rates of trees and eliminate undesirable trees, and (3) harvesting at optimum tree size. These practices produce trees that are evenly spaced and approximately equal in size and age. Managed forests that will result from a full implementation of these practices will be structurally different from natural forests in that they generally will have fewer tree species, reduced structural complexity, and a lower mean age of trees. Timber management thus tends to simplify natural forest systems.

Changes in vegetation structure caused by timber management have a tremendous potential impact on the assemblages of bird species that inhabit forest systems. One change that may have a particularly strong impact is the reduction or elimination of older forest age classes. Predicted age of trees at harvest in the Pacific Northwest now varies from 45 to 140 years depending primarily on productivity of the site. When one considers that coniferous trees often live for well over 200 years, it becomes apparent that predicted harvest schedules will truncate the potential life span of natural forest stands. Old stands of timber now being rapidly liquidated from forest systems (e.g. in Oregon, Beuter et al. 1976) will not be allowed to redevelop under intensive management regimes. Any bird species or group of species closely associated with these older forest age classes may be negatively impacted if such forests are greatly reduced or eliminated (Meslow and Wight 1975).

In the Pacific Northwest, the U.S. Forest Service and Bureau of Land Management are currently developing plans to retain a small portion of commercial lands in old-growth timber. Whether these plans will be successful in the face of increasing demands for timber products remains to be seen.

The purposes of this paper are to examine available information on assemblages of bird species in older forest age classes, and discuss how timber management may affect these species assemblages.

CHARACTERISTICS OF BIRD SPECIES ASSEMBLAGES IN OLD-GROWTH FORESTS

The following examination of birds in old-growth forests is based on the results of 11 breeding bird censuses in various forest types in western North America; most are from the Pacific Northwest. Selection of the censuses was difficult because the term "old-growth" has not been clearly defined. A forest is often considered "old-growth" when it acquires a set of characteristic structural components. Franklin et al. (in press) suggested that 4 primary structural elements characterize old-growth stands of Douglas-fir (Pseudotsuga menziesii) in western Oregon. These elements are (1) large, individualistic Douglas-fir trees with coarse branch systems and deep crowns, (2) large standing dead trees, or "snags," (3) large logs in various stages of decay on the ground, and (4) large logs in streams. Other characteristics mentioned were high coefficients of variation in tree sizes (i.e. a multi-layered canopy), and patchiness of the understory. Franklin et al. (in press) stated that these components begin to appear in a Douglas-fir stand in western Oregon after 200 to 250 years. Undoubtedly, the length of time required to attain old-growth characteristics, and the characteristic components themselves change among forest types and growth sites. Therefore, different definitions based on general structural components and specific needs of old-growth-dependent wildlife may be needed for different forest types in different areas.

Due to the lack of a suitable general definition of "old-growth," the 11 censuses were selected simply on the basis that they were conducted in old (usually 200+ years),

generally undisturbed stands of trees. The sample of censuses is admittedly small, and by no means represents all old-growth forests in western North America. Data for such a complete analysis are not available. What I hope to gain by an examination of these censuses is some suggestion of the differences and similarities among assemblages of bird species in old-growth timber.

Species Richness and Total Bird Density

Results of the selected censuses showed substantial differences in species richness (total number of species) and total bird density (Table 1). Some (much) of these variations may be attributed to differences in the type of census method employed, the size of the study area examined, and identification skills of the observers (Table 1). Variability in these factors probably invalidates any close comparison of community parameters among the censuses. Nevertheless, the data appear to suggest (as might be expected) that bird species richness and total bird density are not necessarily uniform in older age classes of various forest types in western coniferous forests. If this is so, any assessment of the relative magnitude of these parameters in an old-growth forest may best be based on a comparison with the results of bird censuses conducted in younger forest age classes of the same forest type, in the same area, using the same census technique and observer.

Foraging and Nesting Guilds

Despite the wide range of values of bird species richness and total bird density among the selected old-growth forests, there were similarities among proportions of species and individuals occupying various foraging and nesting "guilds" (Root 1967). Grouping species into categories based on ecological and behavioral patterns (i.e. guilds) may provide some insight into the importance of various forest components. Among the foraging guilds (Bock and Lynch 1970), the number of species and individuals in the "tree-foliage-searching" and "ground-brush-foraging" categories were most abundant (Table 2). Species and individuals in the "timber-gleaning" and "timber-drilling" categories were less abundant, while birds in the "aerial-searching" and "hawking" guilds comprised only small proportions of the selected censuses (Table 2). A similar distribution of birds among foraging guilds was noted by Wiens (1975) for western coniferous forests in general.

An examination of nesting guilds (Mannan 1977) revealed that coniferous-tree-nesting birds and hole-nesting birds (i.e. birds that nest primarily in dead trees) comprised, on the average, 37.6 and 29.7 percent of the species, and 42 and 30 percent of the total number of individuals, respectively, in the selected censuses (Table 3). Smaller proportions (less than 16 percent) were occupied by ground- and bush-nesting birds, and other tree-nesting birds (Table 3).

If foraging and nesting guilds are good indicators of the relative importance of various forest components to birds, then, not surprisingly, it appears that coniferous trees are one of the more important structural components to birds in old-growth forests. Snags, or standing dead trees, also appear to support a large porportion of the bird populations in old-growth forests (Meslow and Wight 1975, Mannan et al. in press). Other components, such as the understory tree and brush layers may not support a large number of species or individuals, but nevertheless contribute to the structure of bird species assemblages (see Kilgore 1971).

Questions that arise upon examination of these very general conclusions are (1) how do forest components that are important to birds differ between old-growth stands and younger stands? (2) how does timber management affect these important components? and (3) are there any bird species or groups of species that depend upon structural components found only in old-growth forests?

TABLE 1.--Bird species richness and total density in assemblages of bird species in 11 old-growth coniferous forests in western North America.

Dominant tree species[1] location	Census technique (area covered)	Total number of bird species	Density birds/40.5 hectares
TSHE/THPL - British Columbia (Webster 1969)	spot-map (8.1 ha)	19	435
TSHE - Oregon (Wiens and Nussbaum 1975)[2]	variable circular plot (undefined)	12	1060
TSHE - Oregon (Anderson 1972)[3]	sample count (3.2 ha)	25	819
THPL/TSHE/PSME - Oregon (Wiens and Nussbaum 1975)[2]	variable circular plot (undefined)	15	1170
PSME/TSHE - Oregon (Wiens and Nussbaum 1975)[2]	variable circular plot (undefined)	12	572
PSME - Oregon (Wiens and Nussbaum 1975)[2]	variable circular plot (undefined)	12	720
PSME - Oregon (Mannan 1977)	sample count (5.0 ha)	33	667
PSME - California (Hagar 1960)[4]	spot-map (10.1 ha)	13	238
PIJE-ABCO - California (Bock and Lynch 1970)[5]	spot-map (8.5 ha)	24	184
ABMA/PICO - California (Robert 1966)	spot-map (10.1 ha)	14	304
PSME/PIPO - Arizona (Franzreb 1977)[4]	spot-map (15.5 ha)	36	750

[1] ABCO - *Abies concolor*; ABMA - *Abies magnifica*; PICO - *Pinus contorta*; PIJE - *Pinus jeffreyi*; PIPO - *Pinus ponderosa*; PSME - *Pseudotsuga menziesii*; THPL - *Thuja plicata*; TSHE - *Tsuga heterophylla*.

[2] Raptors were excluded from census results.

[3] Stand selectively cut in 1960s (Anderson 1970).

[4] Results expressed are means of 2 breeding seasons.

[5] Stand selectively cut in early 1800s (pers. comm. Carl E. Bock). Results expressed are means of 3 breeding seasons.

TABLE 2.--Foraging guilds of birds in the 11 selected old-growth coniferous forests.[1/]

Foraging guild[2/]	Mean percent of total species (range)	Mean percent of total density (range)
Hawking	10.0 (6-17)	10.6 (1-16)
Tree-foliage-searching	35.8 (26-43)	44.7 (36-56)
Aerial-searching	0.5 (0-3)	0.1 (0-1)
Timber-gleaning	10.4 (5-17)	13.8 (8-25)
Timber-drilling	10.8 (0-22)	3.9 (0-11)
Ground-brush-foraging	32.3 (25-42)	26.7 (17-35)

[1/] See Table 1.

[2/] After Bock and Lynch (1970).

TABLE 3.--Nesting guilds of birds in the 11 selected old-growth coniferous forests.[1/]

Nesting guild[2/]	Mean percent of total species (range)	Mean percent of total density (range)
Ground-nesting	11.9 (5-17)	15.2 (8-26)
Bush-nesting	11.3 (0-26)	7.2 (0-13)
Tree-nesting (either conifers or deciduous)	8.8 (1-18)	5.5 (0-14)
Coniferous-tree-nesting	37.6 (27-50)	42.0 (29-54)
Deciduous-tree-nesting	0.4 (0-3)	0.2 (0-2)
Hole-nesting	29.7 (17-41)	30.0 (21-46)

[1/] See Table 1.

[2/] After Mannan (1977).

TIMBER MANAGEMENT, OLD-GROWTH FORESTS, AND BIRDS

The effects of complete, or nearly complete overstory removal on the structure of bird species assemblages in old-growth forests has been investigated by Hagar (1960) and Franzreb (1977). Disturbances of this magnitude obviously alter the availability of food sources, nest sites, and shelter; all of which are important factors in habitat selection in birds (Klopfer and Hailman 1965, Hilden 1965, Verner 1975). As might be expected, both Hagar (1960) and Franzreb (1977) noted differences between the cut and uncut areas in total bird density, species richness, and species composition. Hagar (1960) found that in the third year following harvest, total bird density in a cut-over area was greater than in an old-growth stand of Douglas-fir. The high density in the cut-over area was due primarily to a greater number of dark-eyed juncos (Junco hyemalis) and mountain quail (Oreortyx pictus); both species nest and forage on the ground. However, species richness in the cut-over area (9 species) was lower than in

the old-growth stand (13 species). The difference was due primarily to a lower number of birds that nested and foraged in coniferous trees and snags.

Franzreb (1977) found that total bird density was greater in a mixed-conifer old-growth stand than in a similar area where most of the overstory had been removed. Of the 13 species Franzreb (1977) listed as being adversely affected by the logging, 42 percent were species that nested in snags, and 33 percent were species that nested and foraged in coniferous trees. One species, the hermit thrush (Catharus guttatus), nested in dense brush or small trees, and foraged on the ground.

Conversely, of the 10 species Franzreb (1977) listed as being beneficially affected by the logging, 50 percent were also birds that nested in snags. These species included the American kestrel (Falco sparverius), yellow-bellied sapsucker (Sphyrapicus varius), violet-green swallow (Tachycineta thalassina), house wren (Troglodytes aedon), and western bluebird (Sialia mexicana); all of which generally prefer open areas for nesting and foraging. A more complete harvest (i.e. removal of most snags) would probably have reduced the numbers of these species as well.

Hagar (1960) and Franzreb (1977) studied the effects of one aspect of timber management on bird communities - harvesting. Another pertinent avenue of study is a comparison of species assemblages in old-growth stands and managed stands near or at rotation age. Because old-growth stands may eventually be replaced by managed stands, this comparison should suggest some of the differences that will exist between assemblages of bird species in natural forest systems (i.e. those with old-growth forests) and managed forest systems. This sort of information will also indicate what components of old-growth forests need to be actively maintained in managed forest systems.

Unfortunately, few comparisons have been made between assemblages of bird species in managed and old-growth forests; possibly because few older-aged managed stands exist. Mannan (1977) found that bird species richness during the breeding period was greater in a stand of old-growth Douglas-fir (31 species) than in 4 thinned and unthinned stands of Douglas-fir 33 to 70 years of age (18-27 species). Total bird density was also greater in the old-growth stand than in all but one of the 4 younger stands. These differences were due primarily to the absence of several hole-nesting birds in the younger stands. Manuwal and Munger (1978)2/ also found a low number of hole-nesting bird species (0-3) in managed Douglas-fir stands 34 to 64 years of age.

The studies by Mannan (1977) and Manuwal and Munger (1978) suggest that in Douglas-fir forests, species richness and total bird density are greater in old-growth stands than in younger, managed stands. Some evidence supporting this conclusion can be found in the results of studies of avian communities and plant succession (mostly from eastern forests). General trends in birds species richness and total bird density through succession suggest that the replacement of old stands of timber with medium-aged stands (usually dense, pole stands) may result in decreased numbers of species and individuals (Johnston and Odum 1956, Martin 1960, Haapanen 1965, Conner and Adkisson 1975). However, a note of caution must be issued. With the possible exception of the study by Manuwal and Munger (1978), none of the above studies examined intensively managed forest stands. Therefore, any general conclusions about total bird density and species richness in unmanaged old-growth stands compared to younger, intensively managed stands would be speculative at best.

The foregoing discussion has concentrated on inter-stand differences in 2 parameters that characterize species assemblages. Perhaps more important than these comparisons is a consideration of how these inter-stand differences may affect the avifauna in

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2/ Unpublished report submitted to the U.S.D.A. Forest Service, Pacific Northwest Forest and Range Experiment Station, LaGrande, Oregon 97850.

an entire managed forest system (i.e. all forest age classes). This consideration involves examination of individual population densities and should seek to determine if any species will be eliminated (or greatly reduced) by the complete liquidation of old-growth forests. The term "elimination" as it is used here can be thought of in two ways (1) complete absence, or (2) a reduction in density to the point where a species is unable to fulfill its functional role in the system.

One example of a species that apparently depends heavily upon old-growth coniferous forests for its habitat requirements is the northern spotted owl (Strix occidentalis caurina). Based on a roadside call count, Forsman et al. (1977) estimated that spotted owls were 12 times more abundant in old-growth Douglas-fir forests than in second growth stands 40 to 50 years of age. Two of the 5 owls detected in second-growth stands were associated with small patches of old-growth habitat. These results supported Forsman's (1976) earlier conclusion that spotted owls depend on old-growth forests for preferred nest and roost sites.

Several other species, or groups of species, while not dependent on old-growth forests for their existence, do reach maximum densities in old-growth habitat. In many of the studies mentioned above, differences between bird species assemblages in young stands and old-growth stands were due to differences in population levels of hole-nesting birds. In Douglas-fir forests in the Oregon Coast Range, Mannan et al. (in press) found that hole-nesting birds preferred large snags with broken tops as nest sites. McClelland and Frissell (1975) noted similar preferences by hole-nesting birds in Douglas-fir and western larch (Larix occidentalis) forests in Montana. Mannan et al. (in press) also found that breeding densities of hole-nesting birds increased with stand age. They attributed these results to the greater number of large, decayed snags in older forest age classes (Cline et al. in press). One hole-nesting bird that is especially dependent on large snags is the pileated woodpecker (Dryocopus pileatus) (Bull and Meslow 1977).

Lists of other species that may reach maximum breeding densities in old-growth forests have been developed (Meslow and Wight 1975, Franklin et al. in press). Included on these lists, in addition to the spotted owl and pileated woodpecker, are the goshawk (Accipiter gentilis), Vaux's swift (Chaetura vauxi), Townsend's warbler (Dendroica townsendi), and hermit thrush. These species, and many others, require further examination before conclusions can be drawn about their relationships with old-growth forest habitat.

important when one considers the lack of information on these topics. Answers to the above questions about "how much, where, and of what size" must then be based on economic and political considerations. Hopefully, both approaches will retain enough old-growth habitat so that options will remain open for alternative, and perhaps more biologically-based plans in the future.

For the present, an intensive effort should be made to gather information about wildlife in old-growth forests. Initially, a general inventory should be conducted. The wide range of bird species richness and total bird density in the 11 old-growth forests (Table 1) indicates that the inventories should be conducted regionally by forest type. Ideally, the inventories should be conducted in a series of age classes extending from recently established stands to old-growth forests. However, given time and fiscal constraints, it is unlikely that this type of intensive program can be initiated in all forest types. One alternative is to conduct the inventories in old-growth stands and managed stands that represent what will be the oldest age class of intensively managed forests of the future.

Development of an ecological information base on species that inhabit old-growth forests also seems to be of critical importance. Initial efforts should be on those species that are closely associated with the older stands (as determined by the inventories). Emphasis should be placed on examination of nest site selection, productivity, foraging behavior and ecology, territory and home range size, and dispersal capabilities of the young. In addition, some assessment of the lower limits of viable population size must be made. All of these factors are important in the development of sound management programs for old-growth forests and their associated fauna.

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THE CALIFORNIA WILDLIFE HABITAT RELATIONSHIPS PROGRAM: AN OVERVIEW

Hal Salwasser

Regional Wildlife Ecologist
USDA Forest Service, Pacific Southwest Region

John C. Capp

Wildlife Biologist
USDA Forest Service, Rocky Mountain Region

Hugh Black, Jr.

Wildlife Staff Officer
USDA Forest Service, Shasta-Trinity National Forest

Janet F. Hurley

Wildlife Biologist
USDA Forest Service, Pacific Southwest Region

ABSTRACT

The California Wildlife Habitat Relationships (WHR) Program is developing new tools to assist field biologists assess habitat conditions for forest and rangeland wildlife. The systematic organization of existing knowledge on the life histories and habitat relationships of these animals is the core of the Program. WHR is needed to meet the requirements of many laws, policies, and regulations as well as to foster a land ethic in wildland resource management. Major land and wildlife management agencies in California and Nevada, many universities, and one public utility company are cooperating in the Program. WHR is based on the premises that wildlife are products of the environmental features that they use as habitat; that wildland resource management affects those habitats and is subsequently an indirect form of wildlife management; that wildlife habitat requirements must be an integral part of wildland resource planning and management; and that a comprehensive information system covering all species habitat relationships is necessary to facilitate multi-species wildlife planning and management. The Program is consequently structured to develop such an information system, apply it to management processes, and provide for continual improvement in both the system and its application. WHR is administered by a statewide coordinator and

leaders from each of four working zones in the state.

KEYWORDS: habitat, wildlife, land use planning, ecosystem, management, California.

INTRODUCTION

Program Goal

The California Wildlife Habitat Relationships Program is being developed to provide natural resource managers with a system for obtaining information on the responses of wildlife species and their habitats to land management alternatives. The Program emphasizes the practical application of knowledge and experience about wildlife and their habitat requisites to the tasks of identifying wildlife habitat improvement opportunities and of predicting the wildlife consequences of habitat change. The change can be either natural or man induced.

The core of WHR is the systematic organization of information on the life history characteristics of each species, and on the relative capability of different environments to support them. All species of amphibians, reptiles, birds, and mammals inhabiting California's wildland forests and ranges are included (some sub-species are also covered). Environments are classified as wildlife habitats, and described in terms of the habitat elements that provide different arrangements of food, cover, space, and water for wildlife.

The Program of itself will not make nor constrain land management decisions. It will eventually provide an ecologically sound and practical method for integrating wildlife habitat resource data with data on other natural resources for the purpose of assisting decision making administrators understand the wildlife opportunities and consequences of their decisions. We are developing tools to improve the wildlife aspects of the environmental assessment process. Application of these tools hopefully will lead to improved wildlife conservation.

Program Need

The WHR Program is needed to effectively meet the requirements of numerous laws, regulations, and public demands, and to facilitate the evolution of a "land ethic" in natural resources management. The principal national laws affecting public land management agencies are the National Environmental Policy Act of 1969 (NEPA), the Endangered Species Act of 1973 (ESA), the Forest and Rangelands Renewable Resources Planning Act of 1974 (RPA), the Sikes Act of 1974, the National Forest Management Act of 1976 (NFMA), and the Federal Land Policy Management Act of 1976 (FLPMA). Various state laws also affect management decisions.

The central features of these national laws for wildlife resources are indicated by Section 6 of NFMA, "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple-use objectives...", and by Section 2 of ESA, "...provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved...". By law, we must prevent the man-caused extinction of any species, and we must maintain animal community diversity on Federal lands.

Federal agencies prepare regulations to implement these laws. Regulations provide direction for the preparation of Environmental Impact Statements, Environmental Assessments, and various other reports and plans. The regulations for National Forest System Land and Resources Management Planning (36 CFR 219) require that on each

National Forest, "Fish and wildlife habitats will be managed to maintain viable populations of all existing native vertebrate species..." and the "population trends of management indicator species will be monitored and relationships to habitat changes determined." In addition to the legal mandates previously mentioned, we must deal quantitatively with habitats for all species, and with populations of species selected for management attention. This is very difficult to do, and the WHR Program is providing a "first step" on these tasks.

Public demands for wildlife resources range from local to national in scope. They come from individuals, ad hoc coalitions, sportsmen's groups, national conservation organizations and their regional and state affiliates, and from educational institutions. Public interests vary from population levels of single species, such as deer for harvest, to populations and habitats of several species as indicators of ecosystem vitality. These concerns can result in litigation over land and resource management decisions. Often the litigation arises because resource tradeoffs and the consequences of management alternatives are not adequately displayed. The WHR Program will not halt legal action against resource administrators, but it will provide a credible mechanism for portraying the wildlife consequences of their decisions.

Finally, as society's land stewards we have an obligation to promote conservation as "...a state of harmony between man and the land" (Leopold 1966). This can be done only through an ecosystem, or holistic, philosophy about natural resources management. "Living organisms and their nonliving (abiotic) environment are inseparably interrelated and interact upon each other" (Odum 1971), or as Commoner (1971) puts it, "everything is connected to everything else." Our land management actions have multiple effects, many of which cannot be clearly identified. In timber harvest, we affect not only a stand of trees, but also the wildlife depending on that stand as habitat, and the wildlife dependent on those animals as foods. The action causes "ripples" through the entire ecosystem. That is not inherently bad. It merely indicates that we need to better understand the nature of the linkages in our natural resource ecosystems in order to minimize the probability of unintentional ecological catastrophies, such as species extinction, wildlife starvation die-offs, and disease epidemics, and the extent to which we constrain future resource production options.

In summary of why a Wildlife Habitat Relationships Program is needed we have only to look at society's increased concern and sensitivity about environmental quality. It is expressed through laws, regulations, and political pressures, and is founded in a conservation land ethic. Our natural resource ecosystems will be managed to produce high levels of goods and amenities, while maintaining their ecological integrity and vitality. The WHR Program will evolve to provide us with increasingly better mechanisms to meet wildlife resource objectives for all species by utilizing an ecosystem approach to organizing, refining, and applying wildlife knowledge to resource management decisions.

Interagency Involvement

The USDA Forest Service, Pacific Southwest Region, is the lead agency in the Program. Other Federal, State, and private agencies and organizations with responsibilities for wildland resources are involved in providing Program direction and in sharing developmental work. Our mutual concern is for the development of a common philosophy and methodology for organizing wildlife life history and habitat information. The continued evolution and success of the Program is a result of the combined commitments, insights, and hard work of individual line officers, biologists, and others in the USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, California Department of Fish and Game, Southern California Edison Company, USDI Bureau of Land Management, USDI Fish and Wildlife Service, California Department of Forestry, California Universities, and Nevada Department of Fish and Game.

BASIC PRINCIPLES

The Program's underlying principles are adapted from Thomas (1979).

Wildlife as a Product of Habitat

The distribution and abundance of each wildlife species are greatly influenced by the nature, amounts, shapes, location, and juxtaposition of the food, cover, space, and water resources upon which it depends--its habitat. Many other factors as well affect wildlife abundance, such as predation, competition (both resource exploitation and interference types), parasitism, disease, and weather. These latter factors, singly and in combination, act to suppress a species' numbers below the support capability of its habitat. Thus habitat sets the ultimate capability of an area to support any species, and other environmental factors often function to hold populations below that capacity. The WHR Program deals with the basic habitat capability.

Habitat as a Set of Environmental Elements

In a conceptual sense, habitat is a function of the species' needs for food, cover, space, and water throughout its life history. In reality, food, cover, space, and water are the result of stands of vegetation, bodies of water, physical features such as soils, cliffs, slopes, and aspects, and items like snags, rotting logs, and rock outcrops. The different characteristics and arrangements of these factors are what make one area a habitat for deer and another a habitat for goshawks. Of course, the presence of deer is an important element of mountain lion habitat. Our ability to identify wildlife habitat improvement opportunities or to predict wildlife responses to management activities depends upon our understanding of how each species is related to the environmental elements that comprise its habitats, the current conditions of those elements, and how they will change as a result of our activity or inactivity.

In order to define and distinguish the different kinds of wildlife habitat we use a classification system. In the WHR Program, the vegetation elements of habitat are described by broad scale identifiers of vegetation type (e.g., Chaparral, Mixed Conifer Forest, Wet Meadow), by stand classes of size and age of dominant plants (e.g., grass/forb stand, seedling tree/shrub stand, large tree stand), and by canopy cover classes of dominant plants (e.g., less than 40% canopy cover, 40-70% cover, and 70% or more cover). Other habitat elements are also included in the system; e.g., snags, decaying downed logs, seeps, perches, rimrocks.

Wildland Resource Management is Wildlife Management

All land and resource management activities affect at least some of the environmental elements that constitute habitat for some wildlife. It may be timber harvest as a negative effect on spotted owl habitat in dense forest, but a positive effect on shrub dependent deer. Or, it could be livestock grazing as a negative effect on mallard nesting cover around ponds, yet beneficial to forb dependent pronghorn. Every activity alters habitat elements to the extent that some wildlife are benefitted while others suffer. In this regard, wildland resource management is wildlife management.

Wildlife Needs in Land Use Planning

In many areas of the West, wildland management activities other than those directly considered to be wildlife management have a much greater impact on wildlife than do wildlife projects. Timber management, livestock grazing and fire management are prime examples. These activities are in effect the wildlife manager's primary and most feasible habitat management tools. To get desired wildlife habitat benefits from these activities wildlife managers must be involved in the planning and assessment processes; they must know how each species of concern is related to its key habitat

elements; and they must have a mechanism for applying that knowledge to the decision process. Wildlife habitat needs must be an important consideration in wildland resource planning and management.

A Wildlife Habitat Relationships Information System

A systematic approach to information organization and application is needed to deal with all wildlife in all habitats in the increasingly complex and intensive field of resource management. The system must incorporate the best of existing information, and provide for continual refinement as new data are acquired. In developing such a system for the WHR Program we are concerned with the following criteria:

1. The system should be based on well accepted ecological principles.

2. The system should be practical and comprehensible by professional field biologists and other resource professionals.

3. The system should eventually incorporate all important aspects of species' life histories and habitat relationships relevant to resource management.

4. The system should be structured to be compatible with resource classifications used by other disciplines; e.g., timber typing, vegetation classifcation.

5. The system should facilitate integration of wildlife habitat assessments with on going management processes; e.g., land use planning, project planning and assessment.

6. The system should be dynamic in the sense that refinements and improvements of the information base are a planned feature of the system.

7. The system should provide a common terminology for all professionals working in wildlife habitat management.

In brief, the WHR Information System is being designed to be an integral part of the total resource management process, not to be a separate, single resource system.

PROGRAM STRUCTURE

There are three basic parts to the California WHR Program; Information System, Applications, and Program Improvement. They are highly interdependent.

The Information System

The Information System is a synthesis of existing knowledge. It therefore mirrors the present strengths and weaknesses in that knowledge. Two things have come to light in this regard; we know something about the habitat needs of every species, and most of what we know is very difficult to express as a quantitative relationship between population dynamics and habitat conditions. In developing the Information System we have constructed an organizational framework for making what is known easily accessible to field biologists.

We fully recognize that precision is the weakest aspect of our model. At this time, we are more concerned with generality and realism; precision will come as our understanding of wildlife habitat relationships becomes relevant to actual sites. The model is designed to encompass the best understood life history attributes of each species and their habitat needs. What we have now is a general model of wildlife habitat relationships for use in broad scale assessments of wildlife habitat resources.

The Information System is currently composed of three products; Species Notes, Species Habitat Relationships Information File, and Specific Management Documents. Each Species Note is typically a one page description of key life history information, the habitat element requirements of the species, selected references, and a geographic distribution map. The notes are synthesized from literature and personal experience by specialists working on contract for the Program. The notes are designed to bridge the gap between the scant information in a typical field guide, and the detail of an exhaustive literature review.

The Species Habitat Relationships Information File is currently both operational and undergoing rapid development. It was initially designed as a matrix of species relationships with vegetation types, stand classes, and cover classes, and with special habitat elements. The relationships are indicated by an index of relative capability to support breeding, feeding, and resting activities of each species over a many year period. Capabilities are currently classed as optimum - the vegetation conditions are capable of supporting relatively high densities of the species; suitable - capable of supporting intermediate densities; marginal - not capable of supporting a self-sustaining population; and not a habitat for the species. Recent evaluation of this capability classification has lead us to propose future improvement by rating capability in relation to the role of specific vegetation conditions in population dynamics. Under the new system (Table 1) high capability vegetation conditions would potentially support positive recruitment (an increasing population or a stable population that produces a dispersal excess); moderate would support neutral recruitment (a stable population with no dispersal excess), and low capability would not support a self-sustaining population (inhabited primarily by colonizing individuals).

Table 1. Proposed system for rating the habitat capability of vegetation types in the California Wildlife Habitat Relationships Program.

Relative Habitat Capability	Recruitment* / Mortality		Emigration / Immigration
High	G.T. 1	or	G.T. 1
Moderate	~ 1		~1
Low	L.T. 1		L.T. 1

* Recruitment is here considered to be the addition of reproductive age individuals from within the population.

The original habitat relationships matrix is currently being augmented by placing life history and niche information into each species' information file. While the exact details of the information file are still evolving, it is intended that future versions will contain information on the following for each species:

1. Species identifiers (codes, numbers, names).

[illegible]ographic distribution.

history attributes.

[illegible] parameters.

5. Habitat capability of vegetation stand conditions.

6. Relationships to other environmental elements as habitat.

7. Relative abundance.

8. Legal and management status.

Information files for portions of the state are currently accessible through two computer programs; QWICK QWERY (CACI 1973) [1/] for batch mode at the USDA Fort Collins Computer Center, and WHIMP (Marcot pers. comm.) for interactive processing on minicomputers.

Specific Management Documents are still in the developmental phase. They will be patterned after the chapters in Thomas (1979), and will likely be localized modifications of that seminal work. These documents will be designed to provide additional detail on habitat management alternatives for selected species such as mule deer, goshawks, pronghorn, and others, and for special habitat elements such as snags, riparian areas, and old-growth forest. Current efforts concern the development of habitat models for mule deer as a corollary to California's deer management planning effort.

Applications

The development and implementation of procedures for using the information System in wildlife habitat assessments are now underway in many areas of California. A key point in this work is the recognition that the Information System is not a planning or assessment process. Planning and assessment should follow the logical process of: 1) identifying issues, questions, or goals, 2) establishing rules or criteria for gathering information to evaluate conditions relative to those issues, 3) gathering the data and information needed, 4) performing the evaluation, and 5) establishing the management prescriptions needed to meet stated objectives. Wildlife biologists should function at each of these steps as members of the management team.

The Information System is intended to greatly strengthen the biologist's ability to deal with all wildlife at steps 3 and 4. The System is thus both a potential information source and a tool for evaluating habitat capabilities. It does not replace a professionally competent biologist who is capable of integrating site specific wildlife habitat conditions with the general information contained in the system, and who is able to write management prescriptions to meet wildlife objectives.

The WHR Information System is being used both manually and through computer access on projects such as timber sales and in land and resource management planning. As this work proceeds, new methods of making wildlife habitat assessments and habitat capability predictions will be tested and refined. It is our intent to publish these as WHR Applications Notes and to make these new techniques available through periodic training sessions.

1/ "The use of a trade, firm, or corporation name does not constitute an official endorsement of or approval by the U.S. Department of Agriculture of any product of service to the exclusion of others which may be suitable."

Program Improvement

Program Improvement is currently focused on the Information System. The initial information in the System includes many subjective evaluations; best guesses of wildlife specialists. Many, if not all, of these evaluations still need to be field verified, and modified when appropriate.

We are currently supporting investigations of bird community relationships with forest seral stages (Verner 1980), wildlife relationships to hardwoods, wildlife community characteristics of old-growth forest ecosystems, and single species studies on bighorn sheep, pine marten, and other wildlife. The results of these studies will in part be used to improve the resolution of the Information System. It is hoped that improved models for assessing wildlife habitat capability will also result from the studies.

Program Improvement will be a continuing part of the WHR Program. Feedback from field biologists using Program products will be crucial. Field application and evaluation is the most important aspect of Program Improvement.

PROGRAM ADMINISTRATION

Working Zones

The WHR Program was initially guided by a Steering Committee chaired by a Forest Supervisor. In order to complete an initial Information System for a large portion of the state in a short time the committee assigned responsibilities to four working zones; Western Sierra, Southern California, North Coast Cascades, and Northeast Interior (Figure 1). Each zone includes 3-6 National Forests, and is mandated to produce a Zone Specific Information System. Eventually, these four Systems will be incorporated into a standardized statewide system. Progress in each zone is listed in Table 2.

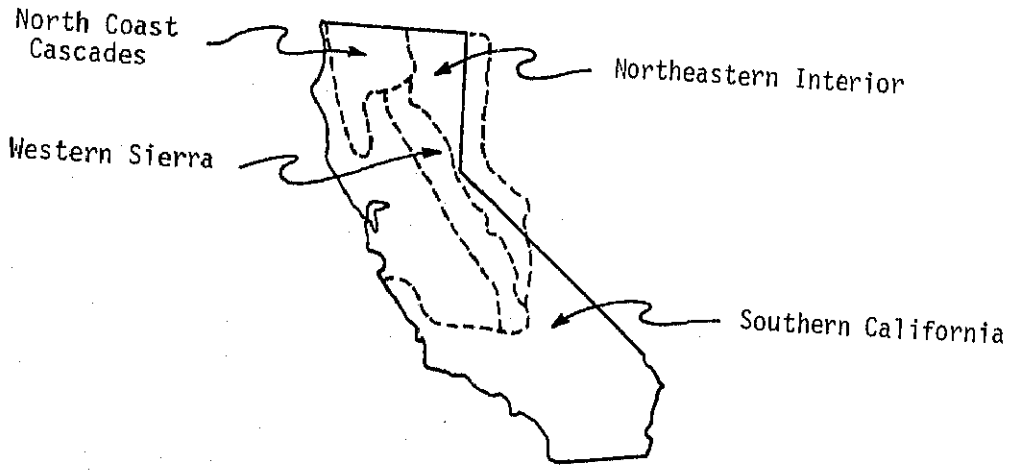

Figure 1. Working Zones of the California Wildlife Habitat Relationships Program.

Table 2. Progress of the working zones of the California Wildlife Habitat Relationships Program. An "x" denotes completion. A year denotes anticipated completion.

Working Zone	Species Notes	Habitat Relationships Matrix	Expanded Information File	Computer Access	Training Program
Western Sierra	x	x	'81	x	x
Southern California	'80	'80	'81	'80	'80
North Coast Cascades	x	x	x	x	x
Northeast Interior	'81	'81	'81	'81	'81

Statewide Coordination

Coordination and direction for developing the Program in each zone and for the state as a whole is lead by the Program Coordinator, a Zone Leader from each zone, and cooperating agency representatives (Table 3). Technical aspects of the Program are handled by the Technical Group, which is composed of individuals working on all aspects of the Program in each zone. The Steering Committee now composed of the Program Coordinator, the USDA Forest Service, Pacific Southwest Region, Fish and Wildlife Staff Director, and one Forest Supervisor from each zone, provides policy direction and administrative support. As the Program expands to cover other portions of the state, appropriate agency line officers will be added to the Steering Committee. We hope to eventually have a Wildlife Habitat Relationships Program that covers all species in all environments of California, and that provides wildlife biologists with an improved ability to insure that California's wildlife habitat resources are prudently managed.

Table 3. Administrative structure of the California Wildlife Habitat Relationships Program.

Working Group	Composition
Steering Committee	Program Coordinator-currently PSW Regional Wildlife Ecologist PSW Region F&WL Staff Director Zone Forest Supervisors-currently 4
Zone Leaders Group	Program Coordinator Zone Leaders-currently 6; 2 are co-leaders Agency Representatives-currently 3 non-FS representatives
Technical Group	Program Coordinator Technical Assistant Zone Technicians Research Cooperators

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WILDLIFE RELATIONSHIPS AND FOREST PLANNING

Steve Egeline

Biological Sciences Planner
Sierra National Forest
1130 "O" Street
Fresno, California 93721

ABSTRACT

The complexity of the "wildlife resource" is vastly greater than any other resource area that the public or private sector manages. To address this complexity, knowledge of all the species has been collected in a single reference (the Wildlife Habitat Relationships Program or WHR) in such a manner that both analysis and decisions can be intelligently made.

The issue in wildlife resources planning is not which habitats are to be retained or even which are more important. The primary issue is what distribution of relative abundances among all the habitats will provide the most desirable mix of wildlife within the demands for individual species and within ecological considerations for wildlife diversity. The WHR program has begun to enable land managers and biologists to evaluate effects in a manner meaningful to address the issues and concerns.

The question of "old growth" habitat, what it is and how much might be desirable is discussed as an example of WHR application in forest planning. Evidence from past descriptions ecological theory and species adaption patterns obtained from WHR data indicate that "old growth" consists of distinct habitats and the relative abundances of these habitats are currently much different than those existing prior to the influence of modern man. The implications of this analysis to forest planning are discussed.

KEYWORDS: Habitat, wildlife, land use planning, ecosystem, old growth, management, diversity.

A species' habitat consists of all the environmental features that provide the food, cover, space and water necessary for population survival. This Huchinsonian concept of habitat and ecological concept of species survival is the basis for the wildlife-habitat relationships currently being developed (Thomas 1979, Salwasser 1980).

Pressure to ensure all species' survival has been manifested in legal action by various groups ultimately resulting in a plethora of laws and regulations (Salwasser et al. 1980). These legislations and interpretations contain such words and phrases as "... untrammeled by man's...," "...maintain viable populations...," "...diversity of plant and animal communities...," "... natural forest...," "...wildlife resource(s)," and "public"1/. Few, if any, of these terms or concepts have been formally defined in relationships to land management planning. In reality, the lack of formal, written declaration of meaning for these terms is a problem only to lawyers and planners since the legality of a forest land management plan is ultimately decided by interpretation of the letter of these laws (i.e., the above phrases) in a court-room. The writing of these and many other regulations on human behavior is an attempt to legislate morality, in this case an ecological morality, and I believe it can be readily demonstrated throughout history that moral legislation fails miserably as soon as the moral atmosphere changes. Unfortunately, moral atmospheres change more rapidly than laws can be promulgated and infinitely more rapidly than ecosystems can react.

These problems of moral, ecological, legal interplays impact directly on the wildlife planner since the forest land management plan is written according to law in response to public needs and demands (i.e., morals) within the context of the forest's ecosystems.

In the absence of direct definitions, I have made some interpretations and formulated conceptional frameworks that will be used in wildlife planning on the Sierra National Forest. The first concept is that there is no "wildlife resource." In reality, each species is a resource in itself, therefore, the term is "wildlife resources." This may seem somewhat simplistic but it is not. A very great majority of people concerned about "wildlife," both professional biologists and pressure groups, do not have the conception of all wildlife species when they address the wildlife resource. Generally, concern about the "wildlife resource" and planning for wildlife is done in the conceptual framework of a few, relatively important species that are defined in each person's mind based on his experience, training, and overall background (Warren et al. 1979). However, the legislated morality states "all species" and therefore it must be made abundantly clear to all people (individuals and groups) that the wildlife resources being planned for are indeed each and every species individually.

A second important concept, closely related to the first, is that there is no "public." If the wildlife planner can internalize the fact that every person is an individual and possesses a unique conceptual framework it is less difficult to deal with "public" issues and the wildlife resources. That is, there are 285 million special interest groups which have some, but not all, concerns in common. An analogy might be the "hunters." This group has in common the concern for maintaining high populations of huntable wildlife species. However, some of these hunters are more concerned about bear than deer. This can lead to conflicting viewpoints about road closure policies. Further, some bear hunters may use hounds in their sport and some may not, again splitting the "group." Obviously this can be carried to the logical extreme that I have stated above, but should nevertheless be a part of the wildlife planners' concept of the "public" if he is to deal with conflicting demands for species and/or habitats.

1/ An excellent reference containing the legislation using these terms is "The Principle Laws Relating to Forest Service Activities," Agric. Handbook No. 453.

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management. Many biologists are currently concerned over the interpretation of these theoretical concepts as applied to the planning job, particularly in light of the likely legal interpretation to be made of forest planning efforts. The remainder of this paper deals with these concerns and is a result of my interpretation of the laws, public issues and concepts of theoretical ecology and should not be construed as nationwide Forest Service policy or direction.

I believe there will be some commonality in wildlife issues on a large majority of western U.S. forests, if not throughout the nation. The major items concern uncommon species (i.e., Endangered, Threatened, Rare, etc.), riparian habitat, the effects of roads on wildlife, the influence of vegetation manipulation (i.e., timber management, fuels management, etc.) on diversity and the question of how much "old growth" is necessary for dependent species survival. These concerns, along with nearly any others concerning wildlife and fish, are inextricably intertwined in the fabric of the ecosystems. To illustrate this point let's consider the "old growth" issue in the context of theoretical ecology and such things as "viability" and "diversity."

The overall objective for any forest plan dealing with wildlife should be to determine what proportion of each plant community containing what proportion of each seral stage in what proximities and sizes will yield the best mix of wildlife species and populations levels that meet the "overall multiple-use objectives" as constrained by the ecosystems' abilities. This illustrates the complexity of wildlife planning in that many things other than plant community and/or successional stage determine "habitat."

In approaching this objective it is useful to apply some principles from gaming theory. The first principle is that of uncertainty. Particularly in the area of ecosystems and habitats, it is generally true that there are fewer incorrect decisions than correct decisions. This is often a function of knowledge deficiency, that is, the only reason that there are fewer wrong answers than right answers is that we know, through experience, what the wrong answers are but only know what the right answers are through theory, which has rather nebulous confidence limits, leading to a range of correct answers but no single correct answer. The second precept of gaming that applies and is directly related is that of risk avoidance. This principle states that as the amount at risk increases, the odds must increase in favor of a correct decision or the bet will not be placed.

The application of these principles to wildlife planning should be apparent. Decisions should be as conservative as possible and should be based on the values of the habitats at risk. This is particularly true in decisions concerning vegetative structure. It is relatively easy to correct a wrong decision concerning shrubs for example, since it is relatively easy and quick to "grow" shrubs. However, if an incorrect decision on the amount of old growth needed is made (on the low side) it may be many hundreds of years before it can be corrected, which is obviously too long with respect to the survival of dependent wildlife species.

The approach I've used in dealing with these problems is to assume that viable populations of all wildlife species could be insured if the forest structure (plant communities, seral stages, energy-flow patterns, etc.) mimics the conditions under which the various wildlife species have evolved. The first problem is to determine what the structure was.

In western forests it seems reasonable to assume that no plant community or seral stage has been totally eliminated by modern man. It should therefore be reasonable to

assume that all plant communities and seral stages now present on a forest were also present during the evolution of wildlife species. Thus, our first criteria is to insure in the forest planning process that no extant plant community or seral stage thereof can potentially be eliminated by prescribed activities. While this seems an intuitively obvious decision I believe that each step in the planning process needs to be made visible and apparent, and this in fact is called for by law.

Our second criteria deals with the question of the relative abundances of the various plant communities and seral stages prior to the influence of modern man. Various studies have pointed out that many plant communities were subject to periodic fires (Kilgore 1973; Thomas 1979; Thompson and Taylor 1979) which maintained them in a particular structural arrangement. And that structure differs considerably from the climatic climax structure. In that modern man began effectively controlling these low-intensity fires around the turn of the century, it should also be obvious that few if any people now alive are personally familiar with the pre- modern-man forest. This is apparent when "old growth" forest is considered. This habitat is generally thought of as a large tree, multistoried, dense canopy forest with small openings, a high degree of decadence, and many logs and other debris on the ground. Photographic evidence (Gibbens and Heady 1964; Progulske and Sowell 1974) and the written descriptions by many early explorers including John Muir, John C. Fremont, and various land surveyors does not paint the same picture. The forests described prior to fire control were indeed characterized by large trees, but there the similarity ends. The "natural forest" old growth also had a relatively sparse canopy closure, few but young and vigorous shrubs and little accumulation of litter or logs.

While the evidence for a large-tree, open-canopy forest is fairly apparent, the sample size is fairly limited. Also, in that we are dealing with a "high risk" decision, it would seem desirable to gather as much evidence as possible (i.e., increase the odds of a correct decision) prior to committing a particular ecosystem to an essentially irreversible decision. The Western Sierra Wildlife Habitat Relationships (Verner et al. 1980) has arranged data for each wildlife species in such a manner that the quality (optimum, suitable, etc.) of a particular plant community and seral stage can be determined with some degree of confidence for each species. By examining these data, certain patterns of adaptation can be discerned. Figure 1 illustrates the number of wildlife species that find optimum or suitable living conditions in each of the 70 defined plant community/seral stage combinations. Figure 2 is simply a refinement of Fig. 1 by considering only those species that show strong reaction to canopy closure and tree size. This second group excludes the reptiles, amphibians, and bird and mammal species that depend on such things as water, cliffs, caves, etc. Figure 3 shows how many of these tree/canopy dependent species are most influenced by large trees with closed canopies, large trees with open canopies and smaller trees with similar canopy closures. It is readily apparent that large trees with open canopies (less than 70 percent canopy closure) are an important structure to more species than any other arrangement.

The ecological theories that apply are those of speciation and partitioning. The more abundant and stable a resource is, the more advantageous it is to become specialized on a portion of that resource since specialization reduces resource competition; that is, the resource can be more finely divided without consequence to the species. This leads to the conclusion, supported by the mentioned written and photographic evidence, that "old growth" habitat in fact was primarily the large-tree, open-canopy type with the closed-canopy type being secondary in abundance and stability. However, if one then examines the particular species that require the closed old growth type, one can see that these species are of equal concern with those adapted to open old growth (Table 1).

The conclusion to be drawn is that there are at least two "old growth" habitats; one being large trees with less than 70 percent canopy closure, single layer tree

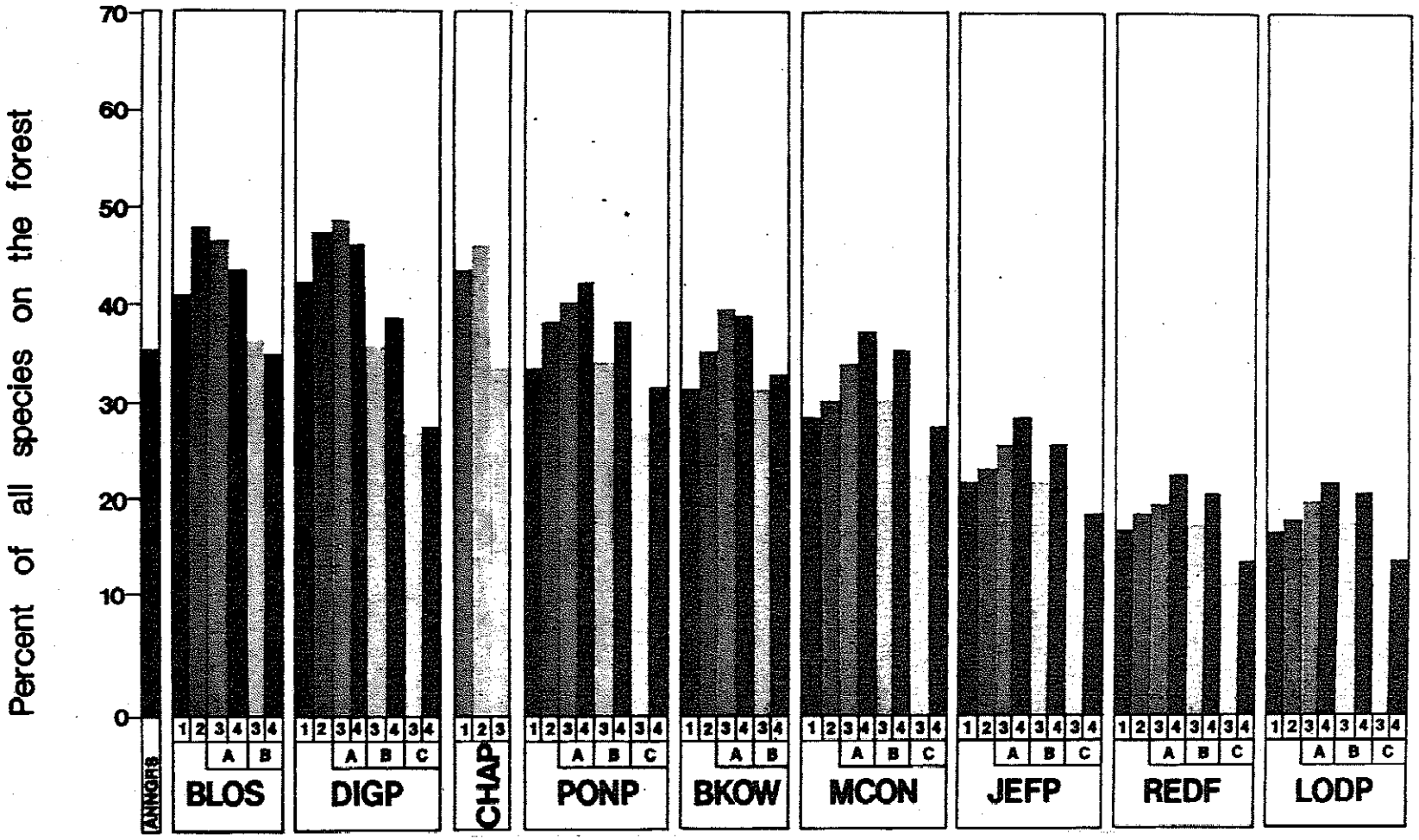

Figure 1. Percentage of all wildlife species that find optimum or suitable breeding, feeding or resting habitat in each of the plant community/seral stage combinations. Plant communities include: annual grasses (ANNGRS), blue oak shrub (BLOS), digger pine (DIGP), chaparral (CHAP), ponderosa pine (PONP), California black oak-white fir (BKOW), mixed conifer (MCON), jeffrey pine (JEFP), red fir (REDF) and lodgepole pine (LODP). Seral stages are: (1) = grass-forb stage, (2) = shrub-seedling-sapling stage, (3) = pole-medium tree stage and (4) = large tree stage. Canopy cover classes are: (A) = from 0 to 39 percent canopy cover, (B) = from 40 to 69 percent canopy cover and (C) = 70 percent or more canopy cover.

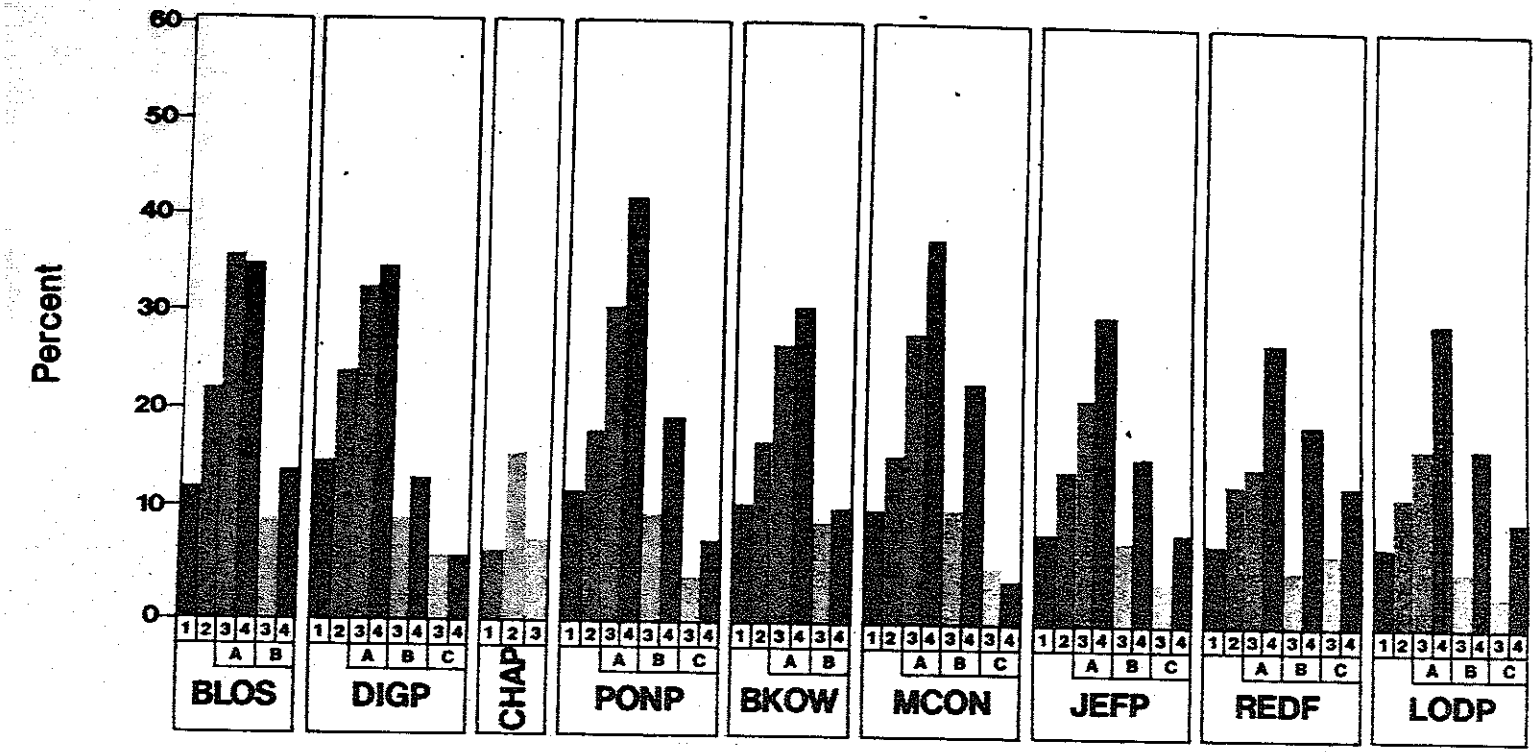

Figure 2. Habitat use by those wildlife species which are strongly influenced by canopy closure and tree size. The height of bars indicates the percent of these species which find optimum or suitable breeding, feeding or resting habitat in each of the plant community/seral stage combinations. For explanation of symbols, refer to Fig. 1.

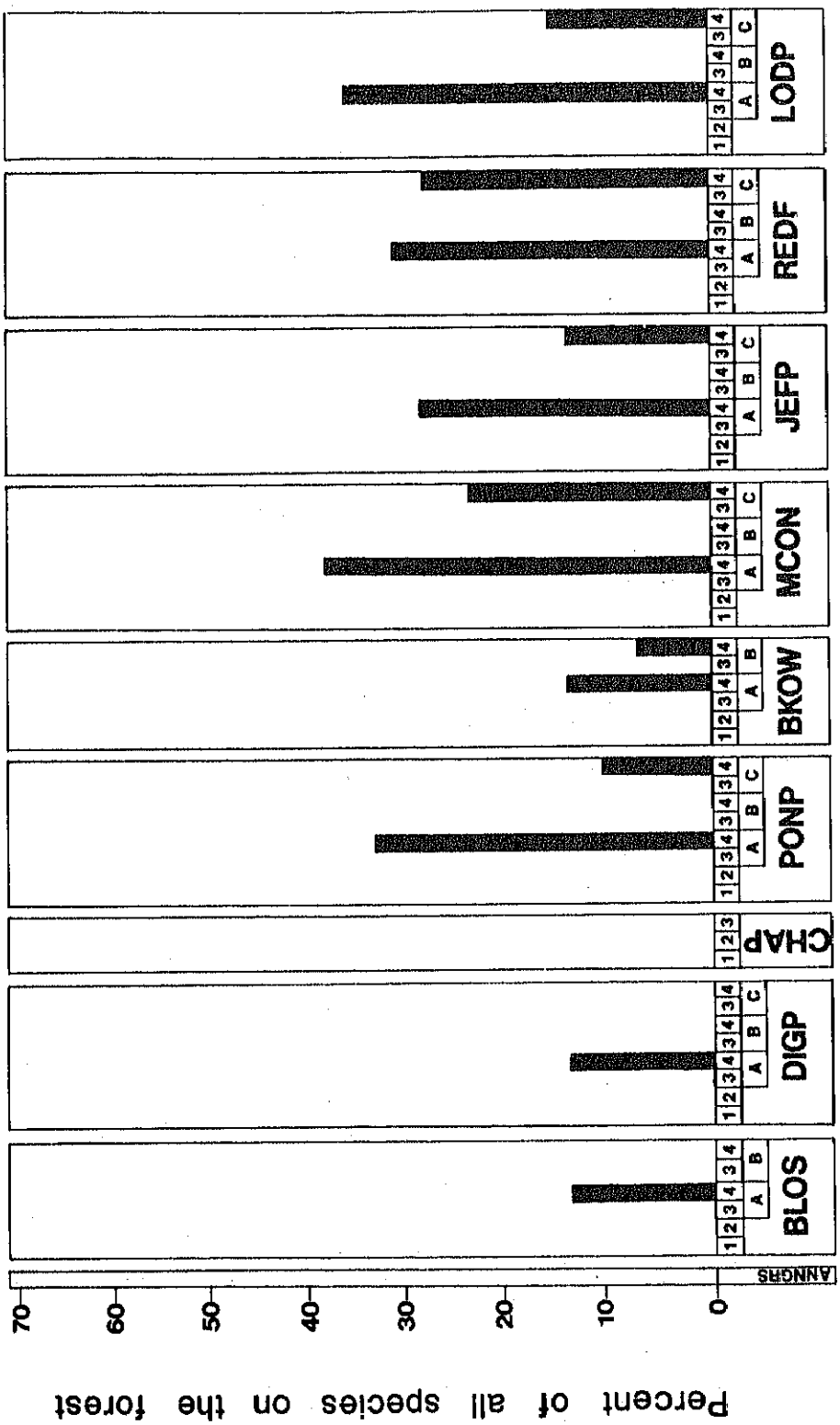

Figure 3. The optimum habitats of those wildlife species whose occurrences seem to be associated with tree size and canopy closure. For explanation of symbols, refer to Fig. 1.

Table 1. Species of the western Sierras whose distribution is influenced by tree size and canopy closure in old growth stands.

Open Old Growth	Closed Old Growth
Yuma myotis *(Myotis yumanensis)*	Wolverine (?) *(Gulo luscus)*
Little brown myotis *(Myotis lucifugus)*	Fisher *(Martes pennanti)*
Ruby-crowned kinglet *(Regulus calendula)*	Marten *(Martes americana)*
Mountain chickadee *(Parus gambeli)*	Black bear *(Ursus americanus)*
Steller's jay *(Cyanocitta stelleri)*	Northern flying squirrel *(Glaucomys sabrinus)*
Olive-side flycatcher *(Nuttallornis borealis)*	Western gray squirrel *(Sciurus griseus)*
Western wood pewee *(Contopus sordidulus)*	Douglas' squirrel *(Tamiasciurus douglasi)*
Black-backed three-toed woodpecker *(Picoides arcticus)*	Golden-crowned kinglet *(Regulus satrapa)*
White-headed woodpecker *(Picoides albolarvatus)*	Brown creeper *(Certhia familiaris)*
Hairy woodpecker *(Picoides villosus)*	Red-breasted nuthatch *(Sitta canadensis)*
Williamson's sapsucker *(Sphyrapicus thyroideus)*	Chestnut-backed chickadee *(Parus rufescens)*
Yellow-bellied sapsucker *(Sphyrapicus varius)*	Pileated woodpecker *(Dryocopus pileatus)*
Common flicker *(Colaptes auratus)*	Great gray owl *(Strix nebulosa)*
Band-tailed pigeon *(Columba fasciata)*	
Blue grouse *(Dendragapus obscurus)*	
American kestrel *(Falco sparverius)*	
Goshawk *(Accipiter gentilis)*	
Pine grosbeak *(Pinicola enucleator)*	
Cassin's finch *(Carpodacus cassinii)*	
Evening grosbeak *(Hesperiphona vespertina)*	
Western tanager *(Piranga ludoviciana)*	
Hermit warbler *(Dendroica occidentalis)*	

canopy, few logs and debris, and sparse, vigorous shrubs; the second characterized by large trees with dense, multilayered canopy and high fuel loadings. The relative proportions of these two types on any given National Forest can best be determined by close consultation with fuels management specialists to determine which areas on the forest were likely not subject to periodic fire due to local topography and soil/moisture regimes. A general conclusion is that the closed old growth likely was associated with high elevation, north slope, riparian areas and that open old growth was associated with hotter, drier sites.

A secondary conclusion to be drawn is that the ponderosa pine and mixed conifer plant communities are not in the same proportion as existed previous to modern man's influence, since many timber stands identified as mixed conifer are, in fact, large ponderosa pine trees with an understory of fire sensitive species such as white fir and incense cedar. This is further supported by the adaptive patterns shown in Fig. 2. More species find optimum habitat in the ponderosa pine type than in mixed conifer.

The management conclusions and recommendations to be made concerning "old growth" might be to manage north-facing mixed conifer communities within one-quarter mile of water as closed old growth in the amount determined as existed naturally (within that 1/4 mile band) by consultation with fuels management specialists. The open old growth might best be managed on poorer timber-producing sites in ponderosa pine and mixed conifer since these sites generally have poor stocking and exhibit the open crown closure characteristic. These open old growth stands can be maintained by periodic individual tree selection cutting and regular prescribed fire.

This will likely result in substantial reduction of closed old growth habitat acreages but it has been argued here that the "natural forest" probably contained substantially fewer acres of this habitat than now exist on most national forests and that those dependent species should be adapted to that situation.

A final note on "old growth" is that species requiring this habitat structure tend to also require rather large patches, therefore old growth of either type should be managed in a minimum patch size of 300 acres and an average of about 600 acres. It should also be apparent that blanket statements of "leave x percent of each timber compartment, capability area, etc., in old growth" are entirely inadequate since the land varies in its ability to produce large trees and the "natural" placement of these habitats should be determined by terrain, surrounding vegetation, etc.

Using these analytical techniques it is also possible to display "diversity." The ecological characteristics of diversity such as richness, equitibility and pattern can all be displayed if acres are substituted for number of species and the size statistics of mean, mode, range and standard deviation are included in the histogram for each community/seral stage. Figure 4 is an example of how this might be done. By displaying components of diversity in this manner and relating the species to the components through a wildlife-habitat relationships concept, it should be relatively easy to address many wildlife concerns by alternative. This can be done by displaying a Figure 2, Figure 3 and Figure 4 for the "natural forest," the "existing forest" and the "future forest" under each of the alternatives and including a wildlife species list for each of the community/seral stage combinations. In this manner, anyone with a concern for an individual species or group of species can determine the effects of the various alternatives. Also, these characteristics of habitat richness, equability and size are measurable, enabling numeric goals to be set and monitored.

A final concept in planning is to consider only those species that depend on a habitat feature that will be reduced by management activities. That is, eliminate species for planning consideration that depend on habitat structures that will increase as a result of some management activity. Also, only consider those plant

communities that will be impacted and finally only consider those management activities that have major, widespread impact in relation to the habitat or species being impacted. This process should result in the "bettering of the odds" in those "high risk" areas and investigation into which decisions are incorrect rather than which are correct. Management direction can then be written to constrain "wrong" decisions rather than to attempt creating "right" decisions. The optimum decision in land management is that which maintains the maximum range of future options within the constraints of current needs.

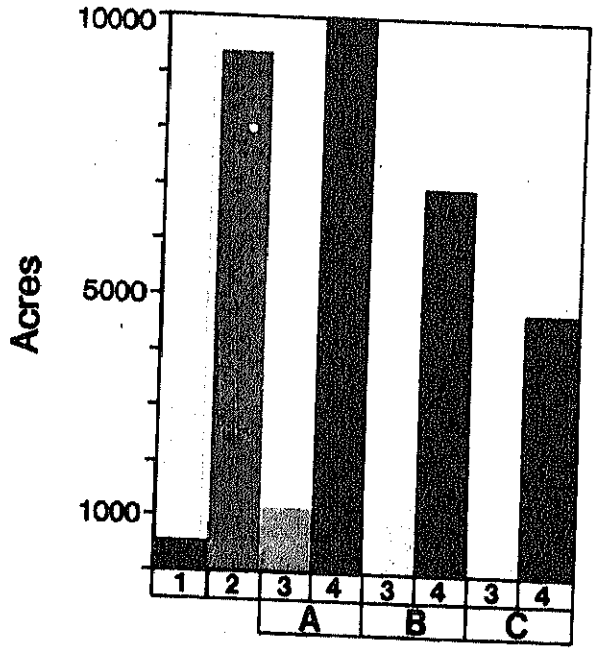

Fig. 4. An example of the acreages (numeric goals) of each plant community/seral stage combination that might be desirable for wildlife habitat--see text.

Acknowledgments

Conversations with Jared Verner, Hal Salwasser, Bruce Marcot, Ed Toth, and Hugh Black, Jr. have served to stimulate the thoughts presented in this paper.

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USE OF A HABITAT/NICHE MODEL FOR OLD GROWTH MANAGEMENT: A PRELIMINARY DISCUSSION

Bruce G. Marcot

Oregon State University
Corvallis, Oregon

> Cautious analyses of ecological interrelationships and extent of behavioral stereotypy are necessary requirements within any forest management program for avian species.
> (McEllin 1979)

ABSTRACT

The basic tenets of a life history approach to a wildlife habitat relationships information base are explored. The life history approach involves detailing habitat, niche, and general descriptors of each wildlife species, and sifting by a computer program to generate groups of functionally-related species. An example of the model to assess stand conditions for obligate old-growth wildlife species is provided.

INTRODUCTION

With recent legislations guiding multiple-resource management on National Fore lands (see Salwasser et al. 1980), the need is great for a multi-species approach fo the assessment of habitat conditions for forest and rangeland wildlife, including nongame birds. Such a multi-species approach should be effectively incorporated int the management system in regard to specialist input and planning needs. The approacl also should be user-oriented and theoretically sound, and should deal with terrestrial vertebrate species of both emphasis and nonemphasis statuses.

This paper explores some of the basic tenets underlying a habitat and niche based multi-species model, and an example of how the model may be used to aid management of older age stands of timber for wildlife.

Model Axioms

The model to be explored is a product of the California Wildlife Habitat Relationships (WHR) Program of the U. S. Forest Service (Salwasser et al. 1980). The WHI involves a compilation of information on the life histories and habitat relationships of species of amphibians, reptiles, birds, and mammals. The goal of the program is t develop new tools to assist biologists and planners to assess occurrence of and chang in wildlife species in relation to existing and potential land management activities.

Conceptual Framework

Warren et al. (1979) define a conceptual framework as a set of axioms characterized by low verifiability and high explanatory power, existing at the "most encompassing level amenable to reasonably complete and adequate verbal articulation." Using this notion, the conceptual framework of the habitat/niche model involves the following tenets.

1. Wildlife habitat is a product of forest and wildland management. Thus, wildland management is wildlife habitat management, desirable or undesirable (Thomas 1979).

2. The degree to which wildlife habitat is managed desirably is dependent on a) the accuracy of prediation and simulation models of wildlife habitat relationships, and b) how well a WHR program can be integrated into multi-resource management schema.

3. All habitat types and their seral stages provide suitable conditions for some groups of wildlife species (Thomas 1979).

The Blue Mountain tome of Thomas et al. (1979) goes a long way in establishing an ecological, interdisciplinary and even socio-political conceptual framework under which a WHR program and subservient models may be subsumed. "Species have niches and habitats" is but one of the numerous tenets of the ecological facet of this conceptual framework. Another and a more general tenet is that "the concepts of species and viable populations are meaningful and are a useful base for conducting wildlife resource management." The mandates of the National Forest Management Act of 1976 (NFMA) specifically addresses management for retaining viable populations. The conceptual framework provides a foundation on which a habitat/niche model may arise.

Theoretical Generalizations

On a logical level down from the conceptual framework, the theoretical generalizations of the approach to be considered here involves a detailing of the life history characteristics of each wildlife species in terms of their environmental needs. The environmental needs of species can be specified along the lines of niche theory and macrohabitat (vegetation type) affiliation.

At the base of this detailing of species' environmental needs is the fundamental tenet that only species' life histories and ecological performances define such (theoretical) terms as (suitable) habitat, viability, facultative and obligate associations with habitat elements, and niche. That is, in contradistinction to an agglomerative approach which may <u>a priori</u> assign species to ecological categories or roles, the proposed life history approach allows such categorization <u>a posteriori</u> in a nonfixed manner. Such ecological categories as life forms, guilds, species types, habitat use, and levels of response to habitat change, are generated in the divisive approach from initial life history details. To be sure, certain categories are initially given, such as the species/habitat matrix, but these are still subsumed in an interacting life history information base and are generative of categories, indices, etc. in a functional and fundamental way. The agglomerative approach, on the other hand, may begin with a particular category or index as "fixed" and from this say things about species' viability or response to habitat shifts.

The enumeration of a species' environmental needs as a theoretical generalization may be regarded in light of the species' habitat ("address") and niche ("occupation"). The WHR information base allows the description of species' habitats (the

species/habitat matrix) and niches (the life history narratives) in a categorical a codifiable fashion. (Emphasis species guidelines and special habitat narratives ca serve to deepen these descriptions.)

A guiding tenet of the division of species into such detailed life history categories, at the level of theoretical generalizations, is that specific life hist information can be used to develop predictive capabilities and simulation models, t help assess (i) effects on the wildlife resource from habitat manipulation and (ii) spatio-temporal arrangement of habitats (macro and micro) necessary to optimize a particular fauna, to meet particular goals for wildlife management. The question o whether this habitat-and-niche approach is either adequate or necessary will not be addressed here.

The life history approach seeks to describe species in details of their behavic and their ecological and geographical distribution. This description may be aided, in part, by adopting a multiple-category niche model. As well, distributions may be described by a combination of habitat descriptors (specifically, vegetation types an their seral or structural stages) and political geographic locators. Additionally, political and social categories, such as legal statuses, taxon/species i.d. numbers, and some indication of social concern or desirability, may further describe each spe cies.

Another theoretical generalization is that the divisive approach may be based on, and feed back into, habitat management as contrasted against single-species popu- lation management. From a multi-species approach, planning scales may widen to en- compass as large a land base as necessary.

Theorems and Models

Following the life history approach, a number of more specific theorems and models may be informally deduced.

Species can be grouped according to functional (habitat and/or niche) relations into species groups or guilds. The grouping of species in the model used below is based on a computerized data storage and access system, the Wildlife Habitat Infor- mation Matrix Program (WHIMP), of the WHR. WHIMP uses multi-level boolean algebra to allow sorting (delineation of habitat or niche parameters) and sifting (grouping of species having the specified characteristics) through the WHR information base, which is set up to represent various categories of each species' habitat, niche, and other general descriptions (Table 1).

Table 1. Species-specific categories of information coded for computer access by the Wildlife Habitat Information Matrix Program.

GENERAL DESCRIPTORS	NICHE DESCRIPTORS	HABITAT DESCRIPTORS
Species common name	Nesting substrate	Vegetation types (by seral or structural stages)
Species scientific name	Diet items	13 zonal types
Taxon/species i.d. no.	Residency	5 azonal types
Legal status	Foraging substrate	Life functions, by levels of use
Abundance, by geographic landbase	Foraging methods	Breeding
	Time of diel activity	Feeding
	Breeding season, range and peak	Resting
	Territory size, range and mean	Season of use
	Breeding home range, range and mean	
	Wintering home range, range and mean	
	Nest height	

Guilds or groups can be a set of species bracketed by management activities as such activities affect the species' habitats and/or niches.

A guild-generating model can make (testable) predictions of species occurrence and changes given a description of a habitat and its manipulations.

A guild-based model can generate indicator species based on detailed functional relations and fealties to micro- and macro-habitat elements.

Several levels of models may be used in the life history approach: (1) simple storage and sifting access of WHR information for a generalized predictive tool; (2) statistical treatment of particular, sifted information; and (3) higher-level ecological or mathematical assessments of within- and between-group parameters, e.g. indices of niche/habitat breadth and overlap, for more site-specific predictions.

Further, each species needs to be described in detail (niche, habitat, and general descriptors) in order to effectively combine species management needs, such as by optimizing habitat diversity for particular groups of species.

Wildlife management may be thought of, in part, as the descriptions of a range of manipulations in a given space, over time, for particular groups of species, that balance or optimize species' needs. This range of management options to attain a particular optimum for wildlife may then be narrowed down according to the needs of other resources. Other resources may similarly identify the range of options that would still meet their management goals and objectives. The overlap of options among different resources' management is the range of total management options, over time, that will meet needs of most or all resources in a given management area. (This overlap may also be derived through linear programming, n-person games, iterative solutions of effects on land base suitabilities from different resources' management options, graphic multi-resource assessment of mini-max or saddle points, etc. While such multi-resource management and planning goes beyond the domain of the present discussion, the life history approach nonetheless may provide deductively-derived models to fit into this schema.)

DEFINITION OF "OLD GROWTH" -- A Brief Discussion

The term "old growth" literally refers to a mature age class of vegetation, a seral descriptor, but stand age is only one variable of a forest habitat. Because various types of land modification - especially timber harvesting - can cause such a wide spectrum of changes, the specific component or structural descriptors of "old growth" that the wildlife manager is most interested in must be clearly defined.

Among the components of "old growth" that may be of importance to wildlife species and that may be affected by land management practices are:

1. large-sized trees
2. old-aged trees
3. decadence of standing vegetation
4. much dead and down woody material
5. uneven-aged vegetation
6. multi-layered vegetation
7. moderate foliar height diversity
8. mesic microhabitats afforded by high canopy closure.

Many components that are associated with old growth can be differentiated and defined according to different wildlife species' needs. Indeed, to arrive at a singular definition of old growth is a dubious goal. What is therefore recommended is to define old growth in terms of any combination of these or other attributes, as

delimited by the needs of species that are to be managed in a particular area. Not all the attributes of old growth as listed above may be met on every site. Managing old growth areas for wildlife therefore may involve knowing the specific requirements of the species to be managed and relating these requirements to the special components outlined above. In this way, old growth can be more efficiently managed on a species-specific basis.

"OLD GROWTH" SPECIES -- Meeting Their Needs

In light of the model axioms developed above, the following theorems may be outlined that guide the use of a life history approach in regard to management of old growth areas for wildlife.

1) "Old growth" -- a lá its components -- may be defined not by a priori definitions and categories, but rather by the environmental (macro- and micro-habitat) needs of the wildlife species that live there.

2) Wildlife species may be identified that use older age classes of forests facultatively and obligately, based on the species' life history patterns that involve macro-habitat components of general seral (age-class) stages of forest stands.

3) Such a facultative or obligate set of species may be further represented by their needs for particular microhabitat components.

4) "Old growth" - using species can be ordinated according to their life history (microhabitat and niche) characteristics to show functional relations.

The wildlife habitat relationships information file was queried using WHIMP to extract species that are associated with old growth habitats as defined above. Specifically, the following queries were made.

Macrohabitat Associations

The habitat descriptors in the wildlife habitat information file was queried to determine which wildlife species are associated with mature or over-mature stages of coniferous vegetation types on the Six Rivers National Forest in northwestern California.

Two classes of associations were defined: facultative and obligate (Table 2).

Table 2. Definitions of facultative and obligate associations of wildlife species with mature seral stages of coniferous vegetation types.

Association	Seral Stage Use: Mature		Early
Facultative			
Breeding or Feeding	O or S	and	O or S
	O or S	and	O or S

Table 2 (cont'd).

Association	Mature		Early
Obligate			
Breeding	0 or S	and	M, N, or?
or			
Feeding	0 or S	and	M, N, or?

Use levels: 0 = optional, S = suboptional, M = marginal, N = no occurrence, ? = unknown.

Many species (12 amphibians, 16 reptiles, 86 birds, and 42 mammals species) were found to be facultatively associated with mature forests for breeding or feeding. However a key interest for managers lies in those 14 bird and mammal species that were identified as obligate associates. The remainder of this discussion will deal with these less flexible species.

Microhabitat Associations and Functional Relations

Table 3 presents selected microhabitat and niche characteristics of the 14 obligate old growth species on the Six Rivers National Forest. Based on this table, a similarity matrix (Table 4) was calculated by using Sørensen's (1948) similarity index. Finally, Figure 1 presents a cluster analysis of the obligate old growth species. The clustering methods followed the two-axis, Euclidean distance method in Mueller - Dombois and Ellenberg (1974).

Table 3. Selected microhabitat and niche characteristics of obligate users of mature forest stands on the Six Rivers National Forest, California. (Information summarized from Marcot 1979).

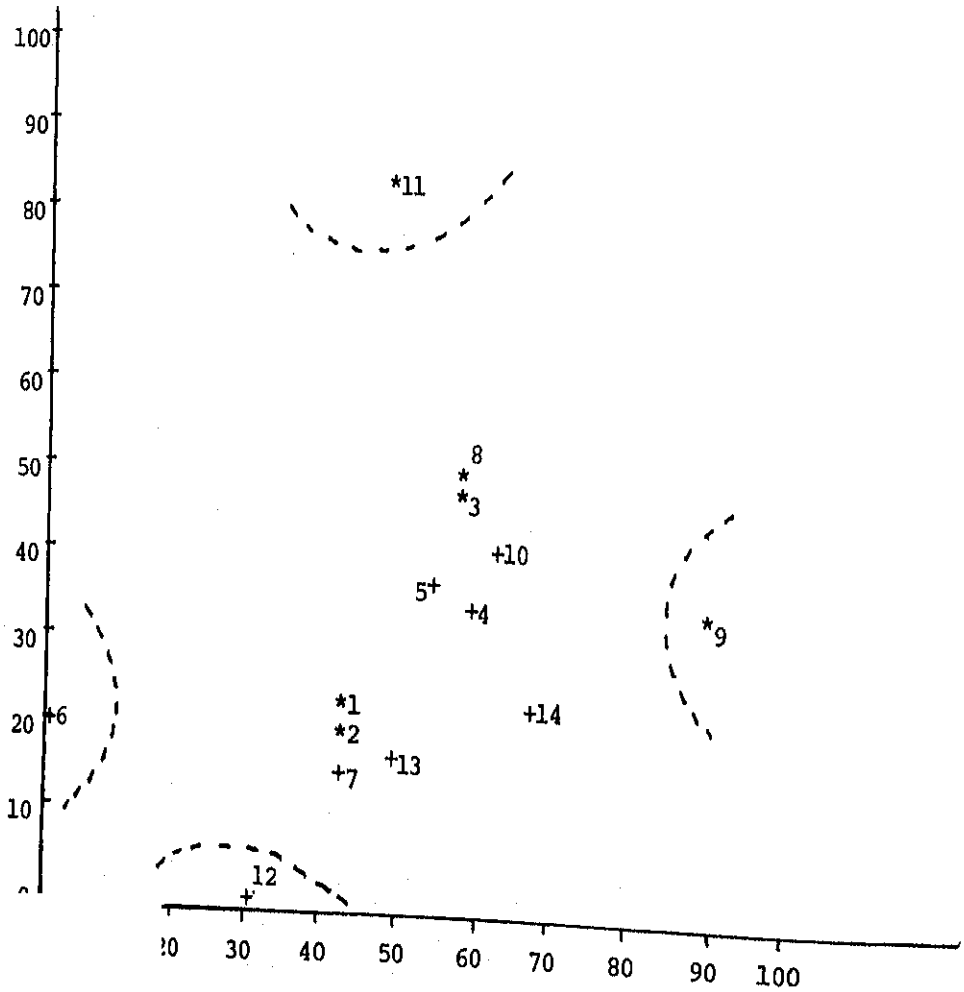
Species	B[a]	F[b]	Küchler vegetation type[c]	Nest height (ft.)	Large size tree users	Diameter at breast height (in.) of nest tree	Territory size (acres)	Old age trees	Decadent standing trees	Dead and down users	Uneven-age vegetation	Mesic Microhabitat/ dense canopy	Riparian users
1. Spotted Owl	MKC	MKC	30-100	X	"large"	300	X	X		X	X	X
2. Pileated Woodpecker	MKC	MKC	15-70	X	20	100		X	X		X	X
3. Brown Creeper	M	M	2-20	?	10	20?	X	X			X		
4. Little Brown Bat	MKC		n/a	X	12	none	X	X			X	X
5. Long-legged Myotis	MKC		n/a	X	?	none	X	X			X	X
6. Wolverine	MKC	MKC	n/a	?	n/a	512,000	?	?	?	?	?		
7. Red-backed Mouse	MKC	MKC	n/a	X	n/a	"small"			X		X	X
8. White-headed Woodpecker	KC	C	5-15	X	24	100	X	X		X			
9. Goshawk	K		20-80	X	12	300	X		X		X	X
10. Marten	K	K	n/a.	X	15	?	?	X	?	?	X		
11. Vaux's Swift	C		n/a		20	"small"		X					
12. Yuma Myotis	MKC		n/a	X	n/a	none					X	X
13. Long-eared Myotis	MKC		n/a		12	?		X			X	X
14. Northern Flying Squirrel	MK		2	X	12	7-10	X	X	X		X	X

[a] B = use for breeding.
[b] F = use for feeding.
[c] Küchler vegetation types: M = Mixed Evergreen Forest with Chinquapin or Rhododendron; K = Klamath Montane Forest; C = Coast Range Montaine Forest. (Source: A. W. Küchler. 1977. A map of the potential natural vegetation of California.

Table 4. Similarity (lower left) and dissimilarity (upper right) matrix of the species characteristics presented in Table 3, as calculated with Sørensen's (1948) similarity index. Rows and columns are numbered according to the species' numbers in Table 3.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-	17	55	33	30	33	28	33	39	33	67	45	45	38
2	83	-	65	44	42	36	23	44	42	45	68	37	37	30
3	45	35	-	44	53	60	68	44	41	47	67	73	47	47
4	67	56	56	-	5	53	33	30	26	29	43	18	6	5
5	70	58	47	95	-	50	30	26	33	37	38	12	0	10
6	67	64	40	47	50	-	33	65	87	71	82	57	57	67
7	72	77	32	67	70	67	-	52	40	44	73	33	44	27
8	67	56	56	70	74	35	48	-	47	53	57	65	65	52
9	61	58	59	74	67	13	60	53	-	37	85	75	50	30
10	67	55	53	71	63	29	56	47	63	-	64	57	43	44
11	33	32	33	57	62	18	27	43	15	36	-	82	64	60
12	55	63	27	82	88	43	67	35	25	43				
13	55	63	53	94	100	43	56	35	50					
14	62	70	53	95	90	33	73	48	70					

Figure 1. Cluster analysis of old-growth obligate species on the Six Rivers National Forest, northwestern California. Analysis was made based on the Euclidean distance method in Mueller-Dombois and Ellenberg (1974), using the similarity matrix data from Table 4. Numbers on the graph refer to species as numbered in Table 3. * = bird species; + = mammal species.



What are the implications of this clustering of obligate old growth species based on their microhabitat and niche characteristics? First, the uneven dispersion of the species throughout the ordination plane suggests that some species are more closely related functionally than others. Therefore, by inference a particular management prescription that would provide for some obligate old growth species may not suffice for all such species.

Second, four species are distinctly different in life histories than the remaining ten, which occupy a central cluster in the graph. Three of these one-species "clusters" may not be considered in the development of old growth descriptions. These are: wolverine (Gulo gulo), which ranges widely, and of which little is known about its distribution and ecology in Six Rivers National Forest; Yuma myotis (Myotis yumanensis), which uses buildings, caves, or mines as well as snags, as hibernacula or nurseries; and Vaux's swift (Chaetura vauxi), which uses hollow trees that may be found in other than old growth stands.

The remaining clusters include spotted owl (Strix occidentalis), goshawk (Accipiter gentilis), and the central cluster of ten species. The large distance between spotted owl and goshawk on the graph suggests different prescriptions for their concomitant management, although managing for one or the other may as well manage for other species in the central cluster.

Thus, two clusters of "old growth obligates" fall out, guided by spotted owl and goshawk as focal species. The stand characteristics necessary for meeting these species' needs are as follows:

CLUSTER 1 - Multistoried Unevenage Stands - these stands are of a multistoried nature usually of pure conifer or mixed hardwood - conifer vegetative composition. The average DBH of both live and dead (snag) trees of the overstory exceeds 20" with a high degree of decadence including heart rot and natural occurring cavities. The canopy is closed (>60%) helping to create a mesic microhabitat at ground level. Dead and down material is present. Close proximity to riparian areas is essential.

Wildlife species associated with this habitat type are:

*1. Spotted Owl
2. Pileated Woodpecker
3. Brown Creeper
4. Little Brown Bat
5. Long-legged Myotis
6. Red-backed Mouse
7. Marten
8. Northern Flying Squirrel
9. Long-eared Myotis

*Not in Cluster II, below.

Other habitat requirements are:

Area Size: To include the territory and/or home range of all species listed requires contiguous habitat >300 acres in size. This may be irregular in shape but long linear strips are unsuitable.

Location: The area needs to be tightly adjoining or incorporating perennial streams or other water bodies.

CLUSTER II - Evenage Stands - these stands are of a single storied, park-like, nature usually of pure conifer or conifer/hardwood mix. Trees are greater than 18" DBH. The prime user of such stands, the goshawk, does not require a high degree of decadence or snags for its needs. Therefore, such stands may better be termed as an evenage mature forest. However, if such stands are to be used by other "old growth" obligate species decadence and snag requirements must be met. Microhabitats are usually drier but mesic situations are optimal. Crown closure is >60%. Close proximity to riparian areas is essential.

Wildlife species associated with this habitat are:

*1. Goshawk
2. Pileated Woodpecker
3. Brown Creeper
4. Little Brown Bat
5. Long-legged Myotis
6. Red-backed Mouse (?)
7. Marten
8. Long-eared Myotis
9. Northern Flying Squirrel

*Not in Cluster I, above.

The more specific habitat requirements are:

Area Size: To include the territory and/or home range of all species listed requires contiguous habitat >100 acres in size. As with Cluster I, this may be irregular in shape but long linear strips are unsuitable.

Location: Loosely adjoining or incorporating perennial streams or other water bodies.

In addition to these two clusters, a third might be established to account for more open canopy users such as the white-headed woodpecker. It was not considered a major management concern in this discussion.

DISCUSSION

The above clustering is based on gross, nominal data, and such assessment should be considered with caution. Functional relationships between species inferred from such a model could vary with more refined information on species' microhabitats and niches.

Other ecological factors not presently included in this approach may limit the degree of both general and site-specific predictability that resultant models may offer. These factors include: (1) "diversity" of the habitat, including juxtaposition and configuration of different habitat patches (Marcot 1979); (2) species-area and habitat "island" effects (Whitcomb 1977, MacClintock et al. 1977, Johnson 1975, Diamond et al. 1976, Simberloff 1976, and others); (3) interspecific interactions, especially competition and predation; (4) density-independent effects such as weather, which may greatly affect wintering bird populations (Anderson and Ohmart 1976, Fretwell 1972); (5) edge effects (Thomas et al. 1979); and (6) the timing of habitat perturbations.

In general, a multi-species model and information base, using a life history and habitat approach, must be usable by field personnel such as biological technicians and by resource planners, who may or may not have greater training in computerese and ecological theory. The system - to be used in management on a project level (i.e., on a day-by-day level) - must approach a cookbook formula, or at least present access to information on a fundamentally simple level, or else it will not be used.

In conclusion, a life history approach utilizing the model axioms developed above may be useful for assessing habitat conditions on a multiple species basis.

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FACTORS INFLUENCING BIRD POPULATIONS IN SOUTHWESTERN RIPARIAN FORESTS

Robert C. Szaro

Wildlife Biologist
USDA Forest Service, Rocky Mountain Forest and
Range Experiment Station, Tempe, Arizona 85281

ABSTRACT

Riparian forests comprise only a minor portion of the available habitat in the arid Southwest, but support extremely high bird populations. Most birds show a remarkable dependency on water related habitat for breeding areas, wintering areas, and migratory corridors. Bird communities in riparian forests are affected by vegetation type, structure, density, temporal fluctuations, adjacent habitat, recreational use, grazing, and location.

KEYWORDS: riparian forest, bird populations, vegetation type.

Riparian bird populations in the Southwest are affected by a multitude of comple and interacting factors. Riparian habitats range from low desert to high alpine meadows (Pase and Layser 1977). Bird densities, species numbers, and diversity vary with changes in vegetation type, structure, density, temporal fluctuations, adjacent habitat, recreational use, grazing and location (Aitchison 1977, Anderson and Ohmart 1977a and b, Carothers et al. 1974, Stevens et al. 1977).

Riparian habitats are comparatively rare (e.g., less than 1/2 percent of the lar area in Arizona), but the breeding avifauna of the Southwest lowlands shows a remarkable dependency on these water related habitats (Johnson et al. 1977). Of 166 breeding species examined from southern Arizona, southern New Mexico, and west Texas, 77 percent were in some manner dependent on these areas and 51 percent are completely dependent on this habitat (Johnson et al. 1977). Carothers and Johnson (1975) found that over 50 percent of the species breeding in homogeneous Fremont cottonwood stands along the Verde River, Arizona, are exclusively dependent on this habitat for reproduction. Their studies showed no other habitat in North America as important to noncolonial nesting birds.

Riparian areas are important not only to breeding bird populations but to winter residents and migrants as well. Riparian habitats act as concentrators of birds

(Goldberg et al.[1/], Stevens et al. 1977). The value of a given riparian habitat varies from species to species and seasonally for the same species (Anderson and Ohmart 1976).

This paper examines many of the factors influencing riparian bird populations in the Southwest and offers some management recommendations. The discussion follows Lowe's (1964) definition of a riparian association as "in or adjacent to drainageways and/or their floodplains and which is further characterized by species and/or life forms different from that of the immediately surrounding non-riparian climax." This includes vegetation along both perennial and ephemeral stream courses. The area under consideration ranges from western Texas through New Mexico and Arizona to southern California, and includes the southern portions of Nevada, Utah, and Colorado.

VEGETATION

Southwestern riparian habitats include a diverse mixture of trees and shrubs (Hubbard 1977). Communities at the lower elevations consist primarily of mesquite (Prosopis juliflora) and saltcedar (Tamarix chinensis) changing through a continuum of vegetative associations to high elevation woodlands of alder (Alnus spp.) and willow (Salix spp.) (Pase and Layser 1977). Perhaps because of the relatively small amount of riparian habitat in the Southwest and its extreme complexity, little information is available on the range of vegetative types found in this region.

Although there is no site-based classification system for riparian vegetation, Brown et al. (1979) have developed a digitized nomenclature for southwestern wetland biotic communities. This system indicates the potential array of riparian associations in the region (Table 1). Their listing of communities is tentative, and will be modified as more data become available. Yet with only the beginnings of a classification it becomes clear that managing riparian habitats for nongame bird populations will ultimately depend on bird community information from each association.

[1/] Goldberg, Nancy H., N. Joseph Sharber, Laurence E. Stevens and Steven W. Carothers. 1979. Distribution and abundance of nongame birds in riparian vegetation in Arizona. Museum of Northern Arizona, Flagstaff, Arizona and Rocky Mt. For. and Range Exp. Stn., Tempe, Ariz. Unpublished manuscript.

TABLE 1.--Tentative classification of riparian forest and scrub associations in the Southwest (modified from Brown et al. 1979).

Nearctic Wetland Vegetation
Forest Formation
Cold Temperate Swamp and Riparian Forests
Plains and Great Basin Riparian Deciduous Forest
Cottonwood-Willow Series
1. Populus sargenti Association
2. Populus sargenti-Salix amygdaloides Association
3. Populus wislizenii Association
4. Populus spp.-Salix spp. Association
5. Salix exigua Association

TABLE 1. (cont'd.)

- Rocky Mountain Riparian Deciduous Forest
  - Cottonwood-Willow Series
    6. *Populus angustifolia-Salix* spp. Association
    7. *Populus angustifolia* Association
  - Mixed Broadleaf Series
    8. *Acer negundo-Populus angustifolia*-mixed deciduous Association
    9. *Populus angustifolia*-mixed deciduous Association
    10. *Acer negundo* Association
    11. *Acer glabrum* Association
    12. *Acer grandidentatum* Association
- Warm Temperate Swamp and Riparian Forests
  - Interior Southwestern Riparian Deciduous Forest and Woodland
    - Cottonwood-Willow Series
      13. *Populus fremontii-Salix* spp. Association
      14. *Populus fremontii* Association
      15. *Populus fremontii*-mixed deciduous Association
      16. *Populus wislizenii* Association
      17. *Populus acuminata* Association
    - Mixed Broadleaf Series
      18. *Platanus wrightii-Fraxinus velutina-Populus fremontii*-mixed deciduous Association
      19. *Platanus wrightii-Quercus* spp.-*Juniperus* spp. Association
      20. *Plantanus wrightii* Association
      21. *Fraxinus velutina* Association
      22. *Alnus oblongifolia* Association
      23. *Juglans major* Association
  - Californian Riparian Deciduous Forest and Woodland
    - Cottonwood-Willow Series
      24. *Populus fremontii-Salix* spp. Association
      25. *Salix* spp.-*Populus fremontii* Association
      26. *Platanus racemosa*-mixed deciduous Association
      27. *Platanus racemosa-Quercus agrifolia* Association
      28. *Alnus rhombifolia* Association
- Tropical-Subtropical Swamp, Riparian and Oasis Forests
  - Sonoran Riparian and Oasis Forests
    - Palm Series
      29. *Washingtonia filifera* Association
      30. *Washingtonia filifera-Populus fremonti* Association
    - Mesquite Series
      31. *Prosopis juliflora* Association
      32. *Prosopis juliflora*-mixed short tree Association
      33. *Prosopis pubescens* Association
    - Cottonwood-Willow Series
      34. *Populus fremontii-Salix gooddingi* Association
      35. *Populus fremontii* Association
      36. *Salix gooddingi* Association
      37. *Salix bonplandiana* Association
      38. *Salix* spp.-mixed deciduous Association

Swampscrub Formation

- Arctic-Boreal Swampscrubs
  - Rocky Mountain Alpine and Subalpine Swamp and Riparian Scrub
    - Willow Series
      39. *Salix bebbiana* Association
      40. *Salix* spp.-*Alnus* spp. Association
      41. *Salix* spp. Association

TABLE 1. (cont'd.)

Alder Series
42. Alnus tenuifolia Association
43. Alnus tenuifolia-Salix spp. Association

Cold Temperate Swamp and Riparian Scrubs
Plains and Great Basin Swamp and Riparian Scrub
Willow Series
44. Salix spp.-mixed scrub Assocation
Saltcedar Disclimax Series
45. Tamarix chinensis Association
Rocky Mountain Riparian Scrub
Willow-Dogwood Series
46. Salix spp.-mixed deciduous Association
Willow Series
47. Salix spp. Association

Warm Temperate Swamp and Riparian Scrubs
Interior Southwestern Swamp and Riparian Scrub
Mixed Narrowleaf Series
48. Cephalanthus Occidentalis-Baccharis glutinosa-mixed scrub Association
Saltcedar Disclimax Series
49. Tamarix chinensis-mixed deciduous Association
Californian Deciduous Swamp and Riparian Scrub
Mixed Narrowleaf Series
50. Salix lasiolepis Association
51. Salix spp. Association

Tropical-Subtropical Swamp and Riparian Scrub
Sonoran Deciduous Swamp and Riparian Scrub
Mixed Scrub Series
52. Prosopis pubescens-Prosopis juliflora torreyana-Pluchea sericea Association
Saltcedar Disclimax Series
53. Tamarix chinensis Association
54. Tamarix chinensis-mixed scrub Association

Bird community structure is known only from a fraction of these associations and in many of them where data are available, the information is from only a single location and year (Table 2). Breeding bird densities in riparian communities are dependent on vegetation type and generally are much higher in it than in the surrounding habitat (Anderson and Ohmart 1977a, Goldberg et al. 1979). Reported densities range from a high of 1059 pairs/40 ha in a cottonwood area in central Arizona (Carothers and Johnson 1975) to a low of 11 pairs/40 ha in a mesquite area in Nevada (Austin 1970) and a saltcedar area in California (Weinstein and Berry 1978).

Even within the same vegetative association, breeding bird densities, diversity and species richness differ from location to location. For example, density in five Fremont cottonwood plots varied from 425 to 847 pairs/40 ha, species richness from 20 to 28, and diversity from 2.68 to 3.15 (Table 2). Similar differences are found in willow, mesquite, and saltcedar habitats.

TABLE 2.--Breeding bird community parameters: species richness (SR), bird species diversity (BSD) and density (DEN) of selected riparian forests in the Southwest.

Association	SR	BSD	DEN[2]	State	Source
Plains cottonwood (1)[1]	25	2.30	748	CO	Justice et al. 1979
Plains cottonwood (1)	20	2.08	137	CO	Hanka 1979
Cottonwood-willow-pine (6)	33	3.02	348	NM	McCallum 1979
Cottonwood-willow (13)	27	2.67	354	TX	Engel-Wilson & Ohmart 1978
Fremont cottonwood (14)	26	2.98	847	AZ	Carothers et al. 1974
Fremont cottonwood (14)	22	2.53	512	AZ	Carothers et al. 1974
Fremont cottonwood (14)	20	2.68	425	AZ	Carothers et al. 1974
Fremont cottonwood (14)	22	2.71	612	AZ	Carothers et al. 1974
Fremont cottonwood (14)	28	3.15	684	AZ	Stamp 1978
Cottonwood-ash (15)	13	2.46	639	AZ	Goldberg et al. 1979
Cottonwood-ash-willow (15)	19	2.42	510	AZ	Goldberg et al. 1979
Mixed deciduous (18)	17	2.78	193	AZ	Carothers et al. 1974
Mixed deciduous (18)	19	2.61	332	AZ	Carothers et al. 1974
Mixed deciduous (18)	22	2.85	312	AZ	Carothers et al. 1974
Mixed deciduous (18)	21	2.87	359	AZ	Goldberg et al. 1979
Sycamore-live oak-juniper (19)	36	3.29	609	AZ	Barker 1979
Ash-walnut-willow (21)	20	2.16	352	AZ	Goldberg et al. 1979
Ash-mesquite-hackberry (21)	19	2.70	310	AZ	Goldberg et al. 1979
Alder-ash-sycamore (22)	10	2.17	326	AZ	Goldberg et al. 1979
Walnut-mesquite-sycamore (23)	24	2.90	503	AZ	Goldberg et al. 1979
Cottonwood-willow (24)	32	3.55	456	CA	Manolis 1973
Cottonwood-willow (24)	21	2.92	394	CA	Gaines 1973
Cottonwood-willow-mesquite(24)	37	3.15	197	CA	Goldwasser 1978
Willow-cottonwood (25)	20	2.76	197	CA	Ingles 1950
Willow-cottonwood (25)	20	2.38	740	CA	Woodman 1978
Sycamore-coast live oak (27)	21	2.77	348	CA	Gundy & Flanagan 1978
Sycamore-coast live oak (27)	32	3.09	607	CA	Loveless & Loveless 1978
Sycamore-coast live oak (27)	22	2.84	258	CA	McKinnie 1974
Palm oasis (29)	5	1.33	97	CA	Koopman 1979
Mesquite (31)	31	2.74	190	AZ	Anderson & Ohmart 1977a
Mesquite (31)	13	2.35	11	NV	Austin 1970
Mesquite (31)	12	2.33	49	NV	Austin 1970
Mesquite (31)	19	2.60	244	AZ	Stamp 1978
Mesquite (31)	14	2.04	151	CA	Evens 1979a
Mesquite-willow (32)	21	2.33	186	CA	Evens 1979b
Mesquite-saltcedar (32)	10	1.47	167	CA	Jehl 1978
Bebb's willow (39)	7	1.89	286	AZ	Goldberg et al. 1979
Willow (41)	4	1.47	826	AZ	Goldberg et al. 1979
Saltcedar-saltbush (49)	5	1.33	11	CA	Weinstein & Berry 1978
Saltcedar-marsh (49)	23	2.32	43	CA	Cardiff et al. 1978
Arroyo willow (50)	13	2.21	597	CA	Atwood 1978
Willow-mesquite (51)	8	1.62	520	CA	McKernan 1978
Saltcedar (54)	28	2.16	243	TX	Engel-Wilson & Ohmart 1978

[1]Numbers in parentheses refer to Table 1
[2]Pairs per 40 hectares

VEGETATION STRUCTURE AND DENSITY

Bird community differences within vegetative associations partially reflect differences in vegetation structure and density. Carothers and Johnson (1975) found a direct correlation between breeding bird density and tree density in cottonwood areas of central Arizona (Table 3).

TABLE 3.--Average breeding bird densities found on manipulated vs. unmanipulated homogeneous Fremont cottonwood study plots (Carothers and Johnson 1975).

Study plot	Trees/Hectare	Bird Density (Prs/40 ha)
Control	113	1059
Area 2	63	758
Area 3	25	484

They suggest that population densities decline even more rapidly when tree density falls below 25 trees/hectare. Vegetation structure, that is the proportion of foliage present in horizontal strata above the ground, indicates resource distribution in the habitat and thereby affects bird populations (Szaro and Balda 1979). Along the lower Colorado River, foliage density in height intervals of 0.15 - 0.6 m, 0.6 - 1.5 m, 1.5 - 3.0 m, 3.0 - 4.6 and greater than 4.6 m was used in computing a matrix of overlap values. From these values a dendrogram was constructed showing study sites with greatest affinities between foliage density and structure. This analysis indicated six distinct structural types in cottonwood-willow, mesquite, and saltcedar communities along the Colorado (Anderson et al. 1977a). In the six structural types of saltcedar communities, bird density, diversity, and species richness varied from 131 to 503 birds/40 ha, 1.85 to 2.53, and 18 to 25 species. respectively (Table 4) (Anderson et al. 1977b).

TABLE 4.--Densities, diversities and species richness in six saltcedar structural types, lower Colorado River Valley, May through July (Anderson et al. 1977b).

Structural type[1]	Species Richness	Diversity	Density (Birds/40 ha)
I	25	2.50	290
II	20	2.04	503
III	19	1.85	316
IV	18	1.93	241
V	20	2.44	131
VI	24	2.53	226

[1]Structural types differentiated by foliage distribution with foliage volume shifting from a predominance at greater than 9.0 m in type I to a predominance at less than 3.0 m in type VI (See Anderson et al. 1977a for a complete description).

YEARLY AND SEASONAL FLUCTUATIONS

Bird community organization is known to fluctuate yearly (Szaro and Balda 1979), and seasonally (Fretwell 1972) in a wide variety of habitat types including riparian types (Anderson and Ohmart 1977a). Community organization during the spring breeding season may reflect resource-based interspecific competition, while wintering assemblages of birds are probably regulated by harsh and variable climate (Rotenberry et al. 1979). Species diversity, richness, and diversities in riparian plant communities typically show summer maxima and winter minima (Tables 5 and 6)(Anderson and Ohmart 1977a, Rotenberry et al. 1979). Community structure also fluctuates from year to year, probably reflecting climatic events during the nonbreeding season (Fretwell 1972). For example, in a plains cottonwood community over a 7-year period, breeding bird density ranged from 544 to 748 pairs/40 ha, species richness from 23 to 29 species, and diversity from 2.30 to 2.86 (Table 7). Similar fluctuations have been observed in cottonwood-willow, mesquite, and saltcedar along the lower Colorado River (Table 5) (Anderson and Ohmart 1976).

Habitat requirements shift seasonally with changes in community organization because winter requirements of birds are different from breeding requirements (Anderson and Ohmart 1977a). Correlations between population parameters and vegetation structure varied seasonally in the lower Colorado, with habitat breadth being narrowest in winter and broadest in summer. Most species showed some consistency in habitat preference between seasons but only a minority of species showed close associations (Anderson and Ohmart 1977a). Models that predict a high degree of habitat consistency over an entire year must be used with care because many species may not fit the pattern (Anderson and Ohmart 1977a).

Bird community composition changes from season to season as winter and summer residents come and go. Anderson and Ohmart (1976) indicate that ruby-crowned kinglets (Regulus calendula), white-crowned sparrows (Zonotrichia leucophrys), and yellow-rumped warblers (Dendroica coronata) are prevalent members of winter bird assemblages in cottonwood-willow areas along the lower Colorado. However the same species are absent during the breeding season (Table 8). Conversely, ash-throated flycatchers (Myiarchus cinerascens), verdins (Auriparus flaviceps) and brown-headed cowbirds (Molothrus ater) are important summer breeders but of minor importance or entirely absent during the winter. Permanent resident species such as mourning doves (Zenaida macroura), Abert's towhees (Pipilo aberti), and Gambel's quail (Lophortyx gambelii), are major components in all seasons but greatly increase in density during the spring, summer, and late summer periods. Other permanent residents such as the black-tailed gnatcatcher (Polioptila melanura) maintain relatively stable populations throughout the year.

Additional variation during the spring and fall is due to the value of riparian areas as migratory corridors (Rappole and Warner 1976, Stevens et al. 1977, Wauer 1977). Species preferences for riparian areas are shown by differing migrant densities and species diversities in various habitats (Stevens et al. 1977).

ABLE 5.--Seasonal and yearly flux in density and species richness in four veget types along the lower Colorado River Valley (Anderson and Ohmart 1976)

Year	Bird density per 40 hectares by season (species richness)				
	Winter[1]	Spring	Summer	Late Summer	Fall
			Cottonwood-Willow		
1975	119(13)	128(29)	260(20)	273(20)	157(16)
1976	149(34)	194(37)	341(31)	296(35)	166(31)
			Honey-Mesquite		
1975	195(19)	176(28)	239(19)	164(20)	261(24)
1976	258(23)	192(28)	354(20)	208(25)	163(25)
			Saltcedar		
1975	28(11)	105(17)	126(19)	85(12)	76(14)
1976	24(12)	49(12)	237(16)	188(22)	106(21)
			Saltcedar-Honey Mesquite		
1975	58(13)	68(19)	137(19)	213(19)	137(22)
1976	40(15)	115(21)	292(19)	181(19)	176(21)

[1]Winter = December, January, February; Spring = March and April; Summer = May, , and July; Late Summer = August and September; Fall = October and November

E 6.--Seasonal changes in bird community structure in a mesquite bosque (Gavin and Sowls 1975).

ı and Year	Density (Birds/40 ha)	Species Richness	Additional Bird Species Recorded	Bird Species Diversity
ıry 1972	104.4	4	11	1.24
ıary	112.2	4	19	1.18
ı	290.8	11	17	2.11
	539.4	12	19	1.78
	412.5	11	20	1.90
	370.8	10	20	1.91
	241.6	13	17	1.63
t	146.8	8	19	1.78
mber	98.0	5	27	1.43
er	77.6	4	17	1.19
ɔer	48.4	4	14	1.20
ɔer	20.2	2	14	0.68
:y 1973	45.0	4	15	1.08
ıry	85.4	4	19	1.13
	116.0	3	16	1.05
	360.5	9	29	1.57

TABLE 7.--Yearly fluctuations in breeding bird density, species richness and diversity in a Plains Cottonwood community, Jefferson County, Colorado.[1]

Year	Density (Prs/40 ha)	Species Richness	Bird Species Diversity
1978	748	25	2.30
1977	544	29	2.70
1976	581	25	2.55
1975	579	23	2.78
1974	633	24	2.86
1973	571	25	2.71
1972	604	25	2.72
1971	683	24	2.86
$\bar{X}$	618	25	2.69

[1]Compiled from Botorff et al. 1973, 1974; Hurley et al. 1971, 1975, 1977; Justice et al. 1978, 1979; Kingery and Botorff 1972.

TABLE 8.--Seasonal flux in bird densities (Birds/40 ha) for 10 species in cottonwood-willow habitats along the lower Colorado River (Anderson and Ohmart 1976).

Species	Season				
	Winter	Spring	Summer	Late Summer	Autumn
Ruby-crowned kinglet	12.0	3.5	0	0	18.5
White-crowned sparrow	12.0	1.0	0	4.0	13.5
Mourning dove	18.5	25.0	86.5	48.5	27.0
Abert's towhee	5.5	11.5	25.5	24.0	14.0
Verdin	3.0	8.5	11.5	12.5	12.0
Ash-throated flycatcher	0.5	8.0	12.0	8.0	1.0
Yellow-rumped warbler	32.5	19.0	1.0	0.5	31.0
Brown-headed cowbird	0	11.0	22.5	2.0	0
Black-tailed gnatcatcher	6.0	4.5	4.0	3.5	3.0
Gambel's quail	1.5	9.0	24.0	20.5	4.0

ADJACENT HABITATS

Areas adjacent to riparian habitats play a major role in determining the composition of riparian bird communities (Stevens et al. 1977). In their study, riparian plots in central Arizona contained up to 10.6 times the number of migrants per hectare as adjacent nonriparian plots. Adjacent habitats that were of low value to birds promoted a higher concentration of migrants in riparian habitats.

Breeding bird communities in riparian habitats are typically more diverse and with higher densities than their adjacent nonriparian areas (Table 9). However, there is considerable use of adjacent habitats by riparian birds (Goldberg et al. 1979). Pleasants (unpublished manuscript, as cited in Goldberg et al. 1979) studying foraging behavior in northern orioles breeding in sycamore and cottonwood habitats

bounded by sage and chaparral type vegetation, found that the orioles spent 19 to 84% of their time foraging in adjacent habitats. Of the number of breeding bird species reported from the four riparian sites in Table 9, 16 out of 19 (84%), 9 out of 22(41%), 13 out of 24 (54%), and 11 out of 21 (52%) were censused regularly in the adjacent habitats.

The relative productivity of areas adjacent to riparian habitats may account for part of the difference between the bird communities on mixed deciduous and cottonwood areas (Carothers et al. 1974, Goldberg et al. 1979). Birds breeding in the cottonwood areas spend a greater proportion of their time foraging outside the nesting habitat than did breeding birds in mixed deciduous types. The cottonwood areas studied were adjacent to agricultural or second growth fields; and pastures that are highly productive in terms of insect biomass but not in breeding birds. Mixed deciduous woodlands are bounded by mesquite bosques, pinyon-juniper-oak, chaparral and desert scrub-grassland. Insect biomass is lower in these areas than in cultivated fields; each area is inhabited by its own complement of nesting species (Carothers et al. 1974). Thus breeding bird density is higher in the cottonwood sites probably because of (1) an increased food supply and (2) lack of intra- and interspecific competition in the adjacent agricultural areas.

Agricultural use of riparian areas and adjacent habitats is commonplace in the Southwest. Agriculture and the clearing of the riparian strip reduced the total number of birds per hectare per year near Knights Landing, California from 1566 to 106. In contrast there were 2262 birds/hectare-year in combination riparian and agriculture areas (Hehnke and Stone 1978). Agricultural encroachment typically increases seasonal densities of riparian species in the agricultural riparian edge; however 22 riparian species were lost with agricultural encroachment of riparian habitats along the lower Colorado River (Table 10) (Conine et al. 1978).

TABLE 9.--Breeding bird community parameters of four riparian woodlands and their adjacent areas in Arizona (Goldberg et al. 1979)

Location	Habitat[1] Type	Species Richness	Density[3]	Visitors[4]	Standing Crop Biomass[5]	Bird Species Diversity
Ash Creek	21	19(84)[2]	310	25	21,022	2.70
Ash Creek (E)		8	52	25	1,666	1.89
Ash Creek (W)		5	24	27	2,243	1.56
Rucker Canyon	19	22(41)	328	17	16,320	2.95
Rucker Canyon Adj.		4	34	19	1,089	1.33
Turkey Creek	23	24(54)	503	21	39,646	2.90
Turkey Creek (E)		7	99	19	3,529	1.75
Turkey Creek (W)		6	57	15	3,166	1.58
Wet Beaver Creek	18	21(52)	359	14	29,370	2.87
Wet Beaver Adj.		5	80	16	2,338	1.56

[1] See Table 1.

[2] Numbers in parenthesis are the percentage of bird species censused regularly in the adjacent habitats.

[3] Pairs per 40 hectares.

[4] Number of irregular summer species.

TABLE 10.--Riparian species lost with agricultural encroachment (Conine et al. 1978).

Yellow-billed Cuckoo (Coccyzus americanus)
Black-chinned Hummingbird (Archilochus alexandri)
Anna Hummingbird (Calypte anna)
Yellow-bellied Sapsucker (Sphyrapicus varius)
Brown Creeper (Certhia familiaris)
Hermit Thrush (Catharus guttatus)
Western Bluebird (Sialia mexicana)
Blue-gray Gnatcatcher (Polioptila caerulea)
Cedar Waxwing (Bombycilla cedrorum)
Phainopepla (Phainopepla nitens)
Bell Vireo (Vireo bellii)
Lucy Warbler (Vermivora luciae)
Yellow-breasted Chat (Icteria virens)
Indigo Bunting (Passerina cyanea)
Evening Grosbeak (Hesperiphona vespertina)
Pine Siskin (Carduelis pinus)
Lawrence Goldfinch (Carduelis lawrencei)
Green-tailed Towhee (Pipilo chlorurus)
Rufous-sided Towhee (Pipilo erythropthalmus)
Black-throated Sparrow (Amphispiza bilineata)

RECREATIONAL USE

Riparian zones are important to wildlife because they(1) have increased floral diversity and structure,(2) contrast dramatically with the surrounding upland vegetation, and (3) have a large amount of edge (Thomas et al. 1979). People are also attracted to these areas by the hydrological and vegetational characteristics, and by the high densities and diversities of wildlife.

Recreational use negatively affects riparian bird populations directly through disturbance and indirectly by trampling, gathering of firewood, soil compaction, etc. (Aitchison 1977, Thomas et al. 1979). Steve Loe (personal communication) of the Coronado National Forest, Arizona expressed deep concern for the impact of birders using tape recorders to attract coppery-tailed trogons at the south fork of Cave Creek. This activity was banned in hopes of increasing trogon productivity. Breeding bird density and diversity decreased relative to a control site after the opening of a campground in Oak Creek Canyon, Arizona (Table 11)(Aitchison 1977).

TABLE 11.--Effects of a campground before and after opening on the breeding birds of a ponderosa pine-mixed deciduous riparian habitat (Aitchison 1977).

		Campground		Control	
	Year	Before	After	Before	After
Bird Species Diversity	1973	2.19	1.15	2.08	2.34
	1974	2.62	2.42	2.08	2.43
	1975	2.19	2.34	1.83	2.71

TABLE 11 (cont'd.)

Density (Prs/40 ha)	1973	297	178	326	366
	1974	297	223	158	297
	1975	178	257	178	445
Species Richness	1973	12	8	9	12
	1974	16	13	8	12
	1975	10	12	7	17

OVERGRAZING

Overgrazing is almost universally thought to have a severe negative impact on riparian vegetation (Brown et al. 1977, Ames 1977). The effects of overgrazing on riparian habitats are twofold. First, overgrazing in the adjacent watersheds increases the likelihood of torrential flooding; and second, overgrazing eliminates the understory herbaceous layer and stand reproduction (Brown et al. 1977, Davis 1977). On segments of Sonoita Creek, Arizona, where cattle have grazed for at least 50 years, the combination of decreased establishment and normal mortality of the mature trees would eventually either severely reduce in number or eliminate cottonwoods from this forest (Glinski 1977). Bird densities, diversities and species numbers will undoubtedly be negatively affected by these long term changes in habitat structure. Songbird/raptor use and diversity increased 350% within an enclosure along Big Creek, Utah as compared to outside grazed areas after four years (Duff 1979). Stevens et al. (1977) found that adjacent, nonriparian habitats which were not heavily grazed supported a higher migrant passerine density and migrant passerine species diversity than those areas which were more heavily grazed. To date, no grazing plan short of complete removal of livestock by fencing has had any significant effect on riparian habitat (Ames 1977, Davis 1977, Dahlem 1979).

HABITAT ISLANDS

Riparian habitat types usually are linear, lying along water courses and blending into one another along an elevational gradient. However, clearing of many riparian areas has left islands of riparian habitat. There are also riparian islands around localized water sources such as springs and wells. The size of bird populations within a given riparian island depends on both the size of the island and its distance from areas of similar habitat (Johnson et al. 1977). For example, in homogeneous Fremont cottonwood stands along the Verde River, Arizona, breeding bird densities ranged from 425 to 847 pairs/40 ha and include 20 to 26 species (Table 2) (Carothers 1974); while a similar but isolated riparian habitat (1.6ha) at Indian Gardens, Grand Canyon National Park, supported only 10 breeding species with a total density of 198 pairs/40 ha (Stevens et al 1977).

CONCLUSIONS AND RECOMMENDATIONS

Within the southwestern United States there is an impressive variety of riparian vegetative associations. Within each association there is a unique avian community influenced by type of vegetation, structure, density, temporal fluctuations, adjacent habitats, recreational use, grazing, location and other factors. In such a multi-dimensional system it is difficult to develop any generalized management guidelines. Compounding the problem is the fact that our current level of knowledge of bird communities is only at the inventory level for many vegetative associations.

Factors that should be considered when implementing any riparian management plan include: (1) base plans on bird populationsoccurring in all seasons, not merely on breeding bird populations; (2) manage riparian and adjacent areas as a unit; (3) eliminate or greatly decrease grazing; (4) grazing and timber management practices on adjacent watersheds should be conducted in such a ways as to avoid torrential flooding (Brown et al. 1977); (5) provide for controlled recreational use.

Additional specific information is needed to develop management guidelines for the bird communities of each vegetative association, in order to reasonably predict the impact of varying degrees of habitat manipulation and use on the riparian birds of the southwest. Riparian habitats should be managed as the most sensitive and productive North American habitat because of their high value to avian populations.

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RIPARIAN BIRD COMMUNITIES OF THE GREAT PLAINS

Allen A. Tubbs

Lecturer, Division of Biology
Emporia State University
Emporia, Kansas 66801

ABSTRACT

One hundred thirty-six birds utililizing riparian communities in the Great Plains are identified and categorized. Breeding birds restricted to riparian vegetation may outnumber obligates of other grassland communities sevenfold. Sensitive and other decreasing species are discussed. Grazing, water diversion, and land conversion are the most destructive impacts in the region. Wood-harvesting in riparian habitat is an increasing and potentially disastrous practice. Research needs and management approaches are suggested.

KEYWORDS: birds, riparian habitat, grasslands, management

INTRODUCTION

Riparian ecosystems have been found to be among the most productive and valuable wildlife habitats wherever they occur (Hubbard 1977, Sands and Howe 1977, Fitzgerald 1978, Schrupp 1978). Their importance for birds in the western United States has been well established (Carothers and Johnson 1975, Gaines 1977, Wauer 1977, Bull 1978). Riparian habitat is most critical in arid and semi-arid environments of the region. Coincidentally, these areas are under the greatest pressure from human activity, which unfortunately is rarely favorable to conserving such habitat and its avifauna. The riparian ecosystems of the Southwest have been particularly affected due to a large increase in the human population and its demands for water and other resources in the immediate environment and have received some recent ornithological attention (Johnson 1972, Carothers et al. 1974, Johnson and Jones 1977, Anderson and Ohmart 1979). Riparian bird communities of the Great Basin Desert and Great Plains have been less extensively studied (Beidleman 1954, Crouch 1961, Kindschy 1978). The intent of this paper is to examine the riparian portion of the Great Plains, identify and categorize its dependent avifauna, survey negative impacts on such habitat, and suggest ways to help manage these areas for birds.

Definition of Riparian

Riparian habitat could be broadly defined to include all vegetation adjacent to water, however the scope of this consideration will concentrate on woody vegetation along drainage systems, flood plains, and on the banks of lakes and reservoirs of the interior grasslands. Marshes and potholes prevalent in the northern prairies are an integral part of those communities and should be more appropriately discussed in their management.

Description of Area

The Great Plains extends from southcentral Canada southward through the Dakotas, eastern Montana and Wyoming, Nebraska, Kansas, eastern Colorado, western Oklahoma, the panhandle of Texas, and northeastern New Mexico. The area covered by Johnsgard (1979) from 49° latitude south to the Red River separating Oklahoma and Texas, then west from the 95th meridian to the 104th will be treated here. This major portion of the extant plains encompasses 502,000 square miles, of which about 13 percent is deciduous hardwood forest (Johnsgard 1979). The bulk of this forest occurs as extensions of the eastern deciduous forest into the plains states. The quantity of riparian habitat in this vast expanse of grassland (much converted to agriculture) is hard to ascertain. Perhaps an indirect assumption of 1-3% based on Johnsgard's (1979) figure of 1% surface water and the known riparian vegetation of other western states would be a reasonable estimate. Exclusive of impoundments, Küchler (1964) termed the hardwood dominated communities of a riparian nature across the Great Plains, the Northern Floodplain Forest. The rivers and streams of the western plains are bordered and dominated by cottonwood-willow (Populus-Salix) communities, while the eastern portions also support elm (Ulmus), oak (Quercus), hackberry (Celtis), green ash (Fraxinus), Kentucky coffee (Gymnocladus), box elder (Acer), and other tree species. Avian communities of the cottonwood-willow river bottoms in eastern Colorado are among the few riparian ecosystems of the plains that have been studied from a conservation or management perspective (Beidleman 1954, Botorff 1974, Fitzgerald 1978). Other information generally must be gleaned from single species accounts, surveys, and breeding or winter bird counts.

IDENTIFICATION AND ECOLOGICAL ANALYSIS OF GRASSLAND RIPARIAN BIRDS

One must know what species populations breed, migrate or winter in a particular avian community to manage it. The identification of grassland riparian birds is complicated by the fact most authors (Johnston 1964, Rising 1974, Johnsgard 1979) classify birds of the Great Plains states as woodland, limnic, or xeric (Table 1) and emphasize only breeding birds.

Table 1. An ecological analysis of the breeding birds of the Great Plains.

	Woodland		Limnic		Grassland		Xeric		Misc.		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	
Western Kansas (Rising 1974)	63	46	31	22	----	32 (combined)	23	----	12	9	138
State of Kansas (Johnston 1964)	101	58	36	21	23	13	3	2	11	6	174
Great Plains (Johnsgard 1979)	164	51	72	22	36	11	15	4	38	12	325

Breeding Birds

Only woodland and limnic groups contain species that could be considered riprian. Birds of these two ecological affinities constitute 73% (236 sp.) of the 325 birds which have bred in the Great Plains at least once (Johnsgard 1979). Eleven per cent (36 sp.) are restricted to grassland per se, 4% (15 sp.) to xeric communities, and 12% (38 sp.) of a miscelleneous category. Many woodland species are not restricted to riparian habitat, e.g., American Kestrel, Bobwhite, Mourning Dove, Eastern Kingbird, Blue Grosbeak, whereas a few of the limnic types are obligate riparian nesters, e.g., herons, egrets, and Belted Kingfisher. Table 2 lists birds that commonly reside, breed, or winter in riparian vegetation in the Great Plains.

Table 2. Riparian Birds of the Great Plains (Peterson 1947, Robbins et al. 1966, Johnsgard 1979)

Year-round Residents	Breeding only	Winter only
Great Blue Heron	*Double-crested Cormorant	Goshawk
Wood Duck	Great Egret	Bald Eagle
Common Merganser	Snowy Egret	Mountain Chickadee
Hooded Merganser	Cattle Egret	Red-breasted Nuthatch
*Cooper's Hawk	Little Blue Heron	Brown Creeper
*Sharp-shinned Hawk	Green Heron	Winter Wren
Red-tailed Hawk	*Black-crowned Night Heron	Townsend's Solitaire
Golden Eagle	Yellow-crowned Night Heron	Golden-crowned Kinglet
Peregrine Falcon	Turkey Vulture	Ruby-crowned Kinglet
*Merlin	*Black Vulture	Rusty Blackbird
*American Kestrel	Mississippi Kite	Purple Finch
Bobwhite	American Woodcock	Dark-eyed Junco
Turkey	Spotted Sandpiper	Tree Sparrow
Ring-necked Pheasant	*Yellow-billed Cuckoo	Harris' Sparrow
Mourning Dove	*Black-billed Cuckoo	White-crowned Sparrow
*Barn Owl	Chuck-will's Widow	White-throated Sparrow
Screech Owl	Whip-poor-will	Fox Sparrow
Great-Horned Owl	*Ruby-throated Hummingbird	Lincoln's Sparrow
Barred Owl	Scissor-tailed Flycatcher	Swamp Sparrow
Long-eared Owl	Eastern Kingbird	
Saw-whet Owl	Western Kingbird	Total - 19
Belted Kingfisher	Great-crested Flycatcher	
Common Flicker	Ash-throated Flycatcher	
Pileated Woodpecker	Eastern Phoebe	
Red-bellied Woodpecker	Willow Flycatcher	
Golden-fronted Woodpecker	Acadian Flycatcher	
Ladder-backed Woodpecker	Least Flycatcher	
*Red-headed Woodpecker	Eastern Wood [illegible]	
*Lewis' Woodpecker	Western Wood [illegible]	
Yellow-bellied Sapsucker	Tree Swallow	
*Hairy Woodpecker	*Purple Martin	
Downy Woodpecker	House Wren	
Blue Jay	Gray Catbird	
Black-billed Magpie	Wood Thrush	
Common Crow	Veery	
Black-capped Chickadee	Blue-gray Gnat	
Carolina Chickadee	Black-capped [illegible]	
Tufted Titmouse	White-eyed Vir[illegible]	
White-breasted Nuthatch	*Bell's Vireo	

*Bewick's Wren	Yellow-throated Vireo
Carolina Wren	Red-eyed Vireo
Northern Mockingbird	*Warbling Vireo
Brown Thrasher	Black and White Warbler
American Robin	Prothonotary Warbler
*Eastern Bluebird	*Yellow Warbler
Cedar Waxwing	Ovenbird
European Starling	Louisiana Waterthrush
House Sparrow	Common Yellowthroat
Red-winged Blackbird	*Yellow-breasted Chat
Common Grackle	Hooded Warbler
Brown-headed Cowbird	Kentucky Warbler
Cardinal	American Redstart
Pine Siskin	Orchard Oriole
American Goldfinch	Northern Oriole
Rufous-sided Towhee	Scarlet Tanager
Song Sparrow	Rose-breasted Grosbeak
Total - 56	Black-headed Grosbeak
	Blue Grosbeak
	Indigo Bunting
	Lazuli Bunting
	Painted Bunting
	Total - 61

*Blue List (Arbib 1978)

The 117 species listed as year-round or breeding only, account for 45% of the 260 regular breeders Johnsgard (1979) documented for the region. Eastern deciduous forest species that normally don't venture out onto the plains, even via the flood-plain corridors, or only rarely breed in the region (e.g., Red-shouldered Hawk, Golden-winged warbler, Evening Grosbeak) are not included in this compilation. It should be noted that 51% of the birds occupying the primarily grassland communities (which cover over 80% of the land area) are woodland or forest species (Table 1). This is an impressive statistic as woodlands and forests account for only about 15% of the Great Plains surface area. Johnston (1964) reported 58% of the birds of Kansas to be of a woodland habitat affinity and listed 21 species of eastern deciduous forest birds which occur in western Kansas only along river drainages. Rising (1974) stated "the majority of birds that breed or probably breed in western Kansas could be ecologically classified as woodland". The presence of these woodland birds in the plains is almost completely due to the existence of riparian habitat and points out the need for its conservation.

Although none of the Great Plains riparian birds is endemic, they greatly outnumber any nonriparian grouping. This is especially evident in the western portions of the grasslands. Ports (1979) in an ecological study of the birds of Morton County, Kansas, found 58 species in one or more of four communities. Forty of these inhabited riparian vegetation with lesser numbers in each of the other three non-riparian study plots (Table 3). Of the 25 restricted species, 17 were riparian.

Table 3. A habitat analysis of the birds of Morton County, Kansas, summer 1979

Community	Species No.	Species %	Restricted No.	Restricted %
Riparian	40	69	17	68
Shortgrass	33	57	2	8
Sagebrush	31	53	3	12
Agricultural	21	36	3	12
Totals	58 = N		25	100

*raw data from Ports 1979

In a comparison of breeding bird census results, Ports (1979) reported that breeding bird density, species diversity, species richness, and number of individuals all were much higher in a riparian cottonwood-salt cedar plot than in nearby nonriparian plots (Table 4).

Table 4. Avian results for four study plots, Morton County, Kansas. (Ports 1979)

Results Breeding Bird Census Results	Riparian Study Plot Cottonwood-Salt Cedar Woodland	Shortgrass Prairie Buffalo Grass-Blue Grama	Burned Sagebrush-Sand drop-seed Pasture	Sagebrush-Weedy Forb Pasture
Density, Breeding Birds/40 ha.	274	150	28	38
Total Number of Species	22	10	11	13
Number of Breeding Species	14	5	4	5
Species Diversity $\bar{H}$	2.39	1.63	2.15	2.19
Richness				

Other breeding bird densities for Great Plains riparian communities range fr
137 to 748 individuals per 40 hectares (Table 5). Almost all riparian censuses a
higher than other grassland communities and are similar to or greater than breedi
bird densities of the eastern deciduous forest.

Table 5. Breeding Bird Densities for Great Plains Riparian Communities

Community (reference)	Location	No. Species	Breeding Birds/40
Cottonwood-willow (Sawyer and Sawyer 1977 :82)	Weld Co., CO	20	137
Black Walnut, Hackberry Green Ash (Sawyer and Sawyer 1977:81)	Lyon Co., KS	31	254
Cottonwood-salt cedar (Ports 1979)	Morton Co., KS	22	274
Cottonwood-willow Beidleman 1978)	Logan Co., CO	187 (year-round)	341-432 (year-round)
Cottonwood-willow (Sawyer and Sawyer 1977:81-82)	Jefferson Co., CO	25	469-748 (incl. colonial-herons)
Open Cottonwood (Fitzgerald 1978)	Weld/Morgan Co., CO	81	525
Mixed willow-cottonwood (Fitzgerald 1978)	Weld/Morgan Co., CO	89	589

Winter Birds

Aside from Christmas counts and Bald Eagle surveys, there is a dearth of information on birds wintering in riparian ecosystems of the Great Plains. At least nineteen species are known to occur in riparian habitat of the area of consideration only during the winter (Table 2). These added to the 56 year round residents gives a winter total of 75 possible species. Winter densities are still high with up to 232/40 ha. reported (Sawyer 1974). Many of these birds would perish without riparian vegetation for cover and food during the severe winters of the northern plains.

The Bald Eagle is the only endangered bird utilizing grassland riparian habitat to any significant extent. A Bureau of Reclamation survey in Kansas and Nebraska (Busch 1979) showed Bald Eagles to be wintering in increasing numbers on several reservoirs. These riparian habitats provide a waterfowl prey-base and roost trees, and are possibly tied to higher Bald Eagle counts.

Dickson (1978) reported higher numbers of wintering birds in east Texas bottomland hardwoods than in adjacent stands. Other authors (Anderson and Ohmart 1979) found birds reacted less to habitat structure in summer than other times, indicating winter and migrating birds may need more management.

Migration, Dispersal, and Gene Flow

Many investigators have noted the value of riparian habitat as hospitable avenues for the migration or dispersal of birds across grasslands and deserts (Johnston 1964, Gaines 1977, Stevens et al. 1977, Bull 1978). The percentage of eastern birds (about 50% of Table 2) breeding in the Great Plains attests to the importance of the floodplain forests which allows for their westward expansion. Rising (1974) identified the eastern component "moving into" Kansas as woodland and edge species, while those entering from the west were dry woodland types. Black-billed Magpies and Scrub Jays are examples of birds previously isolated from Great Plains grassland communities which have entered the region via riparian vegetation (Johnston 1964).

Riparian corridors have been shown to be of great importance for gene flow and hybridization between eastern and western relatives, e.g., flickers, orioles, grosbeaks, and buntings (West 1962, Johnston 1964, Sibley and Short 1964).

Numbers of migrants appear to be very high in riparian communities. Stevens et al. (1977) reported riparian plots to contain over ten times the number of migrant passerine species as adjacent nonriparian plots and identified several parameters which influence migrant use of riparian habitats. Although not a riparian species as defined here, the Lesser Sandhill Crane and its endangered relative, the Whooping Crane, utilize various riparian sites across the Great Plains in their annual migrations. The large staging area in the vicinity of Kearney, Nebraska, has received much publicity and may be threatened by water demands on the upper forks of the Platte River (Frith 1974, Aronson and Ellis 1979). The value of riparian habitat to migrants and dispersers should be incorporated into management plans for floodplain forests.

Sensitive Species

All grassland riparian birds occur outside the plains region, however, they are all "sensitive" in that they would rarely breed in the area without riparian habitat. It also must be remembered that many have been permanently pushed from portions of their original range as that habitat was decimated.

Cavity-nesters due to their rather specific nest-site selection and territoriality are sensitive in almost all habitats. The harvesting of older trees and clearing of snags have severely reduced the populations of some birds (Scott et al. 1977). Thirty-five cavity-nesters reside in the Great Plains primarily in riparian habitat (Table 6).

Table 6. Cavity-nesting Birds of the Great Plains (Scott et

Primary Nesters	Secondary or Natural Nesters
*Common Flicker	Wood Duck
Pileated Woodpecker	Hooded Merganser
*Red-bellied Woodpecker	American Kestrel
Golden-fronted Woodpecker	Screech Owl
*Red-headed Woodpecker	Saw-whet Owl
Lewis' Woodpecker	Great-crested Flycatcher
Yellow-bellied Sapsucker	Ash-throated Flycatcher
Hairy Woodpecker	Tree Swallow
*Downy Woodpecker	Purple Martin
	*Black-capped Chickadee

	Carolina Chickadee	House Sparrow
	Tufted Titmouse	
	White-breasted Nuthatch	
	Eastern Bluebird	
	Prothonotary Warbler	

*indicates low tolerance to preferred habitat alteration (Stauffer and Best 1980)

Eight of these are on the 1979 Blue List (Arbib 1978) of birds decreasing across the country. The primary excavators would seem to be an obvious choice for featured species management. Their demise would deprive many obligate secondary nesters of homes, increase competition for the few available sites, and promote declines or extirpation of some species. The inclusion of three woodpeckers on the latest Blue List suggests imminent danger and the need for immediate research. Stauffer and Best (1980) found the Red-headed Woodpecker, Common Flicker, Red-bellied Woodpecker, and Downy Woodpecker to have a low tolerance to habitat alteration. There are indications that migratory cavity-nesters are less easily managed than year-round residents (von Haartman 1968).

Twelve riparian birds nesting in other than cavities are also on the 1979 Blue List (Table 2). Riparian birds of Kansas definitely decreasing are the Eastern Wood Pee Wee, Carolina Wren, and Orchard Oriole; those possibly decreasing are the American Kestrel, Scissor-tailed Flycatcher, Eastern Bluebird, and Blue Grosbeak (Zimmerman 1979). Three peripheral species breeding in grassland riparian habitat have been listed by the Kansas Fish and Game Commission as in need of conservation: the Tree Swallow, Black-capped Vireo, and Prairie Warbler. Studies in Iowan riparian communities classify the Wood Thrush, Blue-gray Gnatcatcher, Ovenbird, Scarlet Tanager, and Rufous-sided Towhee as intolerant to habitat alteration (Stauffer and Best 1980). The same authors described the Warbling Vireo and Yellow Warbler as having a low tolerance. There is a definite need to identify and study sensitive species in the riparian areas of the grasslands.

IMPACTS ON RIPARIAN VEGETATION AND BIRDS

Recent symposia have dealt with the various impacts of human activity on riparian habitat (Johnson and Jones 1977, Graul and Bissell 1978, U.S.D.A. Forest Service 1978). Impacts on Great Plains riparian communities are similar to those in other regions. Two hundred fifty thousand acres of riparian habitat are lost annually in the United States (McCormick 1978). Grazing, water use practices, and land conversion are the most widespread and destructive activities in the plains area.

Grazing

When done properly, the grazing of domestic livestock on grasslands is generally compatible with birdlife and may even increase the numbers of some species, although some of these birds may be detrimental to others (e.g., cowbirds and starlings). The effects of overgrazing are obvious in the American West and usually quite harmful to all wildlife. The attractiveness of water in the grasslands to cattle causes major damage to riparian understory vegetation. The tendancy for livestock to congregate and linger around ponds and stream banks results in the elimination of food and cover plants, reduces nest-sites and habitat diversity, and increases soil erosion (Buttery and Shields 1975, Behnke 1978, Crouch 1978, Kindschy 1978). Crouch (1978) reported a 50% loss of cottonwoods over 18 years in a grazed northeastern Colorado bottomland. No grazing system has been shown to be effective in protecting riparian vegetation (Behnke 1979). Kindschy (1978) recommended the removal of livestock

grazing from riparian communities. Overgrazing of grasslands supplying riparian systems can modify runoff patterns and significantly reduce stream volumes or groundwater supplies (Johnson et al. 1977). Fencing, reduction of numbers in an area, and temporal separations can all reduce the severity of damage where cattle must have access to water. In the western Great Plains, riparian vegetation can recover in 5-7 years when protected from livestock (Crouch 1978, Behnke 1979).

Water Use Practices

Two practices stand out which reduce water flow and hence, riparian vegetation in the Great Plains. The first is the intensive pumping of ground water for irrigation in western Nebraska, Kansas, and Oklahoma. The second is the channelization and damming of streams for flood control. Some habitat is created by reservoirs which benefits certain birds, but dams are ecologically short-lived and disruptive eventually silting in while reducing water flow downstream. Channelization can be used as a management tool to increase or optimize meandering in some revegetation projects (Kochman 1979) but is usually harmful to wildlife. Channelization on the Missouri River, for example, has reduced island acreage from 24,000 acres in 1879 to only 400 acres in 1954 in the lower 500 miles of the river (Mathews 1980). Most land adjacent to water is privately owned with legal rights to a certain amount of that water. This coupled with the economics of irrigation usually necessitates litigation to protect critical riparian habitats and their wildlife.

Land Conversion

Land conversion generally accompanies water diversion. Dickson (1978) believed the main threat to birds inhabiting bottomland hardwoods was the conversion of these forests to farms and reservoirs. In eastern Colorado agriculture is the primary user of riparian areas, converting and using floodplains right up to the river in some areas (Mustard 1978). About 82% of the channelized portion of the Missouri River has been put into agricultural cropland (Mathews 1980). This encroachment is occurring on both private and public lands. Kochenderfer (1970) recommended that buffer zones be retained between harvest operations in the Appalachians to maintain water temperature, water quality, stream channel integrity, and the associated riparian vegetation. This practice should be promoted in the plains region also. A 20 foot buffer zone has been suggested as minimal in Colorado stream relocation projects (Kochman 1979).

Wood-cutting

The great increase in the cost of petroleum fuels has brought the haphazard cutting of trees to epidemic proportions everywhere. The floodplain forest of the Great Plains is one of the communities that can least tolerate this assault. Thousands of acres of the very important cottonwood stands along the Arkansas and Platte River drainage systems have recently been butchered to supply southern pulp mills (Borden 1978). This destruction can result in a significant or total loss of avian species from cottonwood-willow woodland. Beidleman (1978) reported a fourfold decrease in spring species, a threefold decrease in wintering birds, a 50-65% decrease in Mourning Doves, Black-billed Magpies, and House Wrens, and the total elimination of Dark-eyed Juncos and Black-capped Chickadees in a highly productive eastern Colorado cottonwood-willow community that was destroyed to a fringe only. Stevens (1980) has located 3009 Great Blue Heron nests in 76 colonies in Kansas which are in cottonwoods in the western part of the state, sycamores in the eastern portion. When nest and surrounding trees were progressively cut over a three year period in Butler County, Kansas, there was a corresponding decrease in the number of heron nests. The colony eventually disappeared. Cavity-nesters are especially vulnerable to mature tree or snag removal.

Tree density and diversity must also be maintained. In an Arizona study, when tree density was reduced 44%, breeding bird pairs dropped 28%. When tree density was decreased to 78%, bird pairs decreased to 54% of normal (Carothers et al. 1974). Stauffer and Best (1980) found sapling/tree species richness and size, snag size, and vertical stratification vegetation to be most related to bird species abundance in riparian communities of Western Iowa. This suggests very selective cutting of tree species and sizes in the nearby plains counterparts to maintain avian populations. Borden (1978) suggested forest-type management through state agencies with federal assistance as the only reasonable way to help landowners and maintain these extremely valuable trees and their associated wildlife. Unregulated tree-harvesting must be curtailed.

Recreational Activities

In general recreational use is not as destructive and irreversible in grassland riparian communities as it is in other biomes. It's more a matter of too little public land concentrating too many users to a few small areas. Of course the problem is more severe nearer urban and suburban locales. Many recreational activities such as hiking, jogging, or bird watching are quite amenable to riparian management. Fishing and hunting in themselves are not greatly harmful, but the vehicles, especially four-wheel drive, that carry the sportsmen can and do cause substantial damage in some areas. Solutions are to restrict vehicle access and to acquire more public land, perhaps partially by way of a public use fee.

Sand and Gravel Mining, Road-building, and Fire

Good discussions of the effects of sand and gravel mining and subsequent reclamation attempts in cottonwood-willow riparian communities can be found in Graul and Bissel (1978). This activity is usually associated with road-building and/or the expansion of suburbs into the grasslands. Because road construction generally parallels streams and rivers, riparian vegetation is often destroyed or deprived of water. Once roads are well established there is little additional impact with the exceptions of "improvements" and human traffic.

Fire can be a positive or negative factor in the maintenance of quality riparian habitat. Grass fires today are usually controlled operations aimed at maintaining high quality forage and rarely destroy large portions of riparian vegetation. The irregular burn patterns into riparian communities may increase avian diversity by creating a maximum "edge effect" (Kindschy 1978). On the other hand extensive fires can reduce nest-sites for middle and low shrub nesters, resulting in a decrease in bird species diversity (Buttery and Shields 1975).

The impacts of sand and gravel mining, road-building, and fire can be severe in some locales and may have to be considered in management procedures, but usually are minor in comparison to grazing, water diversion, land conversion, wood-cutting, and to a lesser extent, recreational activities.

MANAGEMENT RECOMMENDATIONS

1. Riparian habitat in the Great Plains must be identified and classified in a manner similar to Pase and Layser (1977) so managers will know what they have to work with.

2. There is a real need for ecological tolerance studies for breeding, wintering, and migrating birds in riparian habitat of the plains region. Studies along the lines of Stauffer and Best (1980) would be appropriate and valuable for managers.

[illegible] minimum width of vegetational belts; tree density, species diversity, and age class; horizontal (topography) structure; and vertical (vegetative) structure.

3. A determination of sensitive species (rare birds, isolated populations, or colonial nesters) and their requirements (old trees, snags) must be made. These birds may require special treatment, sometimes at the expense of other species, but if the other birds are ubiquitous, consequences may be negligible.

4. In general the enhancement of habitat patchiness and edge will create more species diversity and contribute to ecosystem integrity which the manager should strive for.

5. Migratory corridors and islands should be maintained to prevent the interruption of gene flow, dispersal, and migratory patterns. The retention of buffer zones to human activity will help to achieve this desirable goal.

6. Livestock grazing must be more closely regulated and even eliminated in some areas if riparian vegetation and its dependent birds are to be preserved. Complete protection may be necessary for some years to allow badly abused habitat to recover.

7. Channelization and other flood control or water salvage practices which decrease riparian vegetation must be discouraged or stopped. Litigation may be necessary in many situations.

8. Landowners must be given incentives (tax benefits or state/federal aid, etc.) to encourage the retention of riparian vegetation and slow its conversion to agricultural uses. A landowner-manager cooperative program may be feasible.

9. Recreation in critical or sensitive areas should be limited to nonconsumptive or low-impact type activities. More public land is needed in the plains states but costs are high as most floodplain is rich farmland.

10. Landowners must be educated to the future consequences of extensive tree removal and haphazard tree-cutting. Wood-harvesting should be prohibited in public areas.

11. The effects of mining and road-building should be mitigated to prevent a negative change in riparian communities.

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DESIGNING AND DEVELOPING A PREDICTIVE MODEL AND TESTING A REVEGETATED RIPARIAN COMMUNITY FOR SOUTHWESTERN BIRDS

Bertin W. Anderson and Robert D. Ohmart

Department of Zoology and the
Center for Environmental Studies
Arizona State University
Tempe, Arizona 85281

ABSTRACT

Avian and vegetation data are summarized for 23 vegetational types found in the lower Colorado River Valley. Each type differed from the others in predominant vegetation present and/or in vertical foliage configuration. Principal components analysis was used to indicate which of the 16 vegetation variables used, including measures of volume, patchiness and foliage height diversity, were truly independent variables. None of the original variables was independent; instead there were 3 or 4 independent variable complexes. Among the 7 avian variables for 4 summers and 4 winters, none was independent. In this case there were 2 independent avian variable complexes. Another principal components analysis was conducted using both the avian and vegetation variables, with the intent of showing independent variable complexes, which would reveal relationships between the avian variables and vegetation variables, if any existed. This analysis suggested stronger ties between bird use of the vegetation in harsher winters than in mild winters and in winter relative to summer. It also indicated greater overlap between avian components in summer than in winter. Models developed from these data were used in designing plans for revegetating areas to enhance wildlife. The designs were implemented on a 30-ha dredge-spoil site devoid of vegetation for at least 15 years. Two years after the initial revegetation the area was tested to see if, given the plant species and vegetation structure, the avian densities and diversities conformed to predicted values. Empirical data for summer and fall 1979 revealed avian densities and diversities close to predicted values.

KEYWORDS: Revegetation, riparian, bird, populations.

INTRODUCTION

In June 1972 we began studying the natural vegetation and associated wildlife in the lower 225 km of the Colorado River (Davis Dam, Nevada-Arizona border to the Mexican boundary). The study was divided into two phases. In the first phase, the vegetation was classified and the densities and diversities of wildlife associated

with each vegetation type were determined. These data were used to develop vegetation-wildlife models of various plant communities which theoretically would support large densities and diversities of wildlife. The second phase was the testing of revegetated communities for their wildlife use values. The major focus of the funding agency (Water and Power Resources Service, formerly the Bureau of Reclamation) was to examine the possibility of enhancing existing plant communities for wildlife and reducing water lost through evapotranspiration. Many of our study efforts revolved around the exotic and spreading salt cedar (*Tamarix chinensis*), which uses large amounts of water through evapotranspiration. It also blocks high water or flood flows, and has been found to support relatively small wildlife populations (Anderson et al. 1977, Cohan et al. 1978) relative to many native plant communities.

The second phase, begun in January 1977, was divided into two parts. Initial efforts determined the likelihood of success of reintroducing native vegetation. This involved estimating growth rates and length of time irrigation was required. We also began assessing the costs of community revegetation (Anderson and Ohmart 1979). These efforts were on a 30-ha dredge-spoil site devoid of vegetation; thus even if our efforts were totally unsuccessful, we would not have destroyed wildlife habitat. Part two was begun in January 1978 and determined the difficulties associated with clearing salt cedar (not discussed in this report).

This report is a mixture of theoretical and applied ecology. The first part will be devoted to determining which vegetational variables appear to be important if an area is to support relatively large avian densities and diversities. We will discuss this in relation to wintering and summering bird populations. The purpose of comparison is to gain insight into whether avian responses to the vegetation are stronger during winter, as contended by Fretwell (1972), or during the breeding season (Cody 1974). We will discuss vegetation use in winter and summer for the sake of brevity, but if habitats are to be managed properly for birds, it is imperative that relationships between bird communities and vegetation be studied during all seasons. Finally, we compared bird use of the habitat in the same season over a period of years in order to determine effects of climate on avian habitat use.

Our study of the vegetation in the lower Colorado River Valley led us to recognize 23 vegetation types. In recognizing 23 types, we considered several things. First, although we wanted to recognize all major vegetation types, we also wanted to develop a system which could be easily committed to memory and which would, therefore, have greater utility in the field. We also wanted the vegetation in each category to be sufficiently common to permit adequate study. In this report we present analyses based on data from the 23 vegetation types. This can be considered a fairly coarse-grained approach. A finer-grained approach, within vegetation types, could reveal subtle details obscured by our more coarse-grained approach. Some of these analyses have been completed, but space limitations preclude an in-depth presentation in this report. Judging from preliminary analysis of finer-grained data sets, we do not feel that completed analysis of these data will seriously alter any of the general conclusions made in this paper relative to management.

METHODS

Communities were classified according to dominant vegetation and vertical configuration. This led to the recognition of 23 vegetational-structural types (for details see Anderson et al. 1977). From 2 to 11 avian census lines, each one

either 800 m or 1600 m long, were established in each type. Birds were censused (Emlen 1971) along these lines 2 to 3 times each month.

The annual cycle was divided into seasons based on changes within the bird communities. Winter included December through February, and summer included May through July.

Foliage height diversity (FHD) was determined using the Shannon-Wiener equation (Shannon and Weaver 1949) after obtaining relative volume estimates along each transect using the board technique (MacArthur and MacArthur 1961). Patchiness in the horizontal dimension (PI) was obtained by considering patchiness of the vegetation at 4 vertical layers (0.15-0.6 m, 1.5-3.0 m, 4.5-6 m, and > 7.5 m) in 0.2-ha subplots in areas encompassing 20 or 40 ha. The 0.2-ha plots were located along the census lines within these larger areas (for more details, see Anderson et al. 1978).

All species of trees and shrubs within 15 m of either side of the census line, for its entire length, were individually counted to obtain densities of each species in the census area. Totals for each census line were averaged to obtain a value for a given vegetation type.

The vegetation analysis, usually done in May and June, was used for all seasons. In winter, the volume estimates refer not to actual volume, but to the volume of twigs and limbs with potential leaf-producing capability. FHD and PI in winter refer to the vertical and horizontal diversity in leaf-producing stems.

Principal components analyses (PCA) were employed to evaluate the vegetational and bird population data (Nie et al. 1975). The vegetation variables were analyzed initially with the PCA to determine the number of truly independent vegetation trends (principal components) represented in the data. Each principal component (PC) includes highly intercorrelated variables from the original set. The extent to which the original variables are correlated with a given PC can be used to give that PC a verbal description. Each PC accounts for a particular proportion of the between-vegetation type variance. The sum of the variance accounted for by the PC's is the total variance between vegetation types which could be accounted for with the analysis. It is possible to give each vegetation type a score on each PC reflecting its place on the gradient represented by the component. These scores then replace the original variables and can be used in other analyses, such as regression analysis, analysis of variance, and so on.

The bird variables were subjected to a similar analysis in order to determine the independent avian trends. Each vegetation type was then given a score for each of the avian components.

Finally, in order to determine the bird variable-vegetation variable relationships, a PCA was conducted using both sets of variables. By examining the relationships between the bird and vegetation variables on this new set of PC's, it was possible to obtain meaningful information about vegetation PC-bird PC relationships. We then regressed the scores of particular vegetation PC's with the bird PC's to which a relationship was indicated, using product-moment regressions. The level of statistical significance was determined through an analysis of variance (ANOVA). Where appropriate, data were transformed in order to conform to assumptions regarding distribution normality.

RESULTS AND DISCUSSION

Climate

During the tenure of this study, the winter climatic situation varied from very mild to relatively cold (Table 1). This is important because of its effect on bird community structure. The winter of 1978-79 was the most severe and was preceded by the mildest winter. Winter 1976-77 was relatively cold and dry, while winter 1978-79 was cold and moist. The two mildest winters (1975-76 and 1977-78) were both relatively wet. All summers were similar in that they were hot and dry.

Table 1. Climatological data for five winters in the lower Colorado River Valley.

Year	Mean temperature (C°) High	Mean temperature (C°) Low	Lowest temperature (C°) recorded	Days of frost	Wind (Km/day)	Solar radiation (Lingley's)	Precipitation (cm)
1975-76	21.6	1.4	-7.8	32	152	270	5.8
1976-77	21.0	-0.4	-5.6	52	66	280	1.0
1977-78	20.1	3.9	-1.7	10	64	255	7.8
1978-79	17.3	0.0	-8.9	50	61	271	6.3

Vegetation Principal Components

We used a total of 16 vegetation variables in the PCA of the vegetation (Table 2). The vegetation was anlyzed separately for each year because vegetation types were added in some years, and in all years new census areas were added and/or old ones were lost to burning or land clearing activities. It all 4 years the first PC (VGPCI) represented a complex axis on which Volume, FHD, PI, and the number of cottonwood (*Populus fremontii*)-willow (*Salix gooddingii*) trees (CW) all had high loadings and accounted for between 36 percent and 40 percent of the variance (Fig. 1) In all 4 years the second factor had high loadings for the number and proportion of salt cedar trees and negative loadings for honey mesquite (*Prosopis glandulosa*) and shrubs and accounted for between 22 percent and 26 percent of the variance. In all 4 years PI 0-2 and Volume 0-2 had high loadings and FHD had an intermediate negative loading on the third PC. PC III accounted for an additional 14 percent to 18 percent of the variance. In 3 of the years there was a fourth factor. In the first year, Volume and PI at intermediate levels had
In the second and last years, shrubs and honey mesquite had high positive loadings and cottonwood-willow trees had a moderately high negative loading (Fig. 1). In 1978, the third year, there were only 3 PC's.

Avian Principal Components

The 7 avian variables considered each season included total species, number of species and densities of permanent resident and visiting insectivores (breeding and wintering) and densities of seedeaters and fruiteaters in winter, and densities of Gambel's quail (*Lophortyx gambelii*) and doves in summer. The number of species of seedeaters and fruiteaters was basically the same from place to place, so species numbers were not included as variables for these groups.

Variables	Number of Variables
Volume and Patchiness	
0.0 - 0.6 m	2
1.5 - 3.0 m	2
4.5 - 6.0 m	2
≥ 7.5 m	2
Total Volume and Patchiness	2
Tree Counts (N/ha)	
Cottonwood (*Populus fremontii*)-willow (*Salix gooddingii*)	1
Honey mesquite (*Prosopis glandulosa*) with mistletoe (*Phoradendron californicum*)	1
Salt cedar (*Tamarix chinensis*)	1
Proportion of total trees which are salt cedar	1
Shrubs (N/ha)	1
Quail bush (*Atriplex lentiformis*), Inkweed (*Suaeda torreyana*), Russian thistle (*Salsola kali*), and Smotherweed (*Bassia hyssopifolia*)	
Foliage height diversity (FHD)	1
	16

In winter, the first bird principal component (BDPC I) accounted for between 46 and 56 percent of the variance (Table 3). In all years, total species loaded high on this component. The number of visiting species loaded high on the first component in 3 of 4 winters. Visiting species loaded highest on this component when permanent residents were lowest. Densities of visiting insectivores loaded high in 3 of 4 winters, while those of permanent residents loaded high, or moderately high, each winter on BDPC I. PC loadings for visiting and permanent residen insectivores were most similar during mild winters (1975-76 and 1977-78) and were farthest apart in the 2 harsher winters, suggesting reduced overlap in the 2 group of insectivores when harsher winter conditions prevailed. Seedeater densities sco high on the first component twice and fruiteater densities once (Table 3).

For permanent resident and visiting insectivores, both the number of species and densities had a stronger tendency to load high on the same axis in summer than in winter. BDPC I also tended to account for more of the variance in summer than in winter (Table 3). These points suggest a stronger tendency for potential competitors (for example visiting and permanent resident insectivores) to be in the same place at the same time in summer than in winter, as well as in milder winters relative to harsher winters.

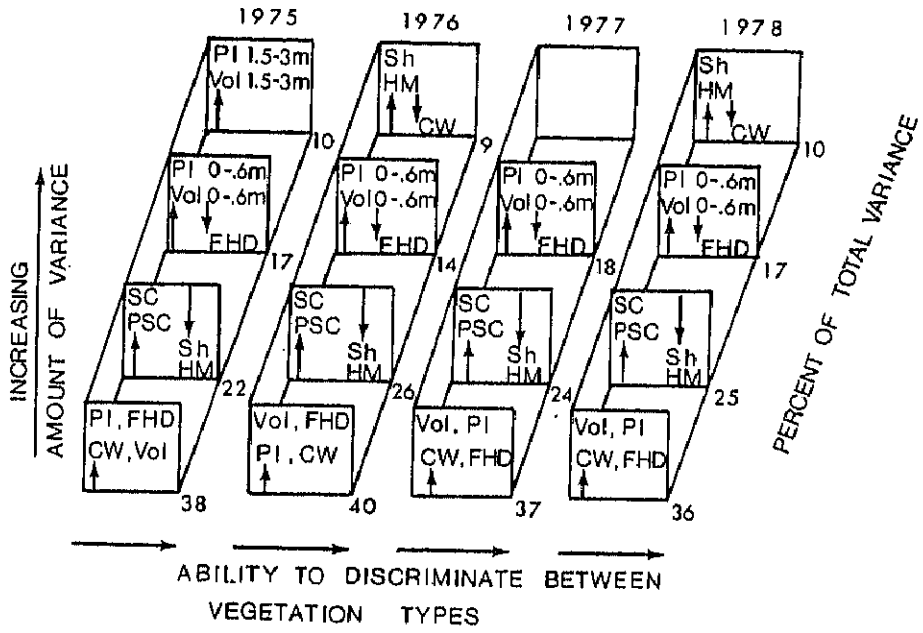

Figure 1. Principal components for each of 4 years among the 23 vegetational types found in the lower Colorado River Valley. Each of the squares in the multidimensional graphs represents a PC. The variance accounted for by each PC lies to the right of the square. The total variance accounted for by the PC's is the sum of the individual PC's. An arrow pointing up from the horizontal axis indicates a positive loading and an arrow pointed toward the horizontal axis indicates a negative loading.

Table 3. Avian principal components during winter and summer in the lower Colorado River Valley.

Season and year	Percent of variance accounted for	Rotated factor scores for avian variables								
			Insectivores							
			Species		Densities		Densities			
		Total species	Permanent residents	Visitors	Permanent residents	Visitors	Seed-eaters	Fruit-eaters	Gambel Quail	Doves
PC I Winter										
1975–76	54	0.95	0.75	0.87	0.85	0.83	0.24	-0.16	–	–
1976–77	46	0.77	0.96	-0.09	0.54	0.16	0.76	0.69	–	–
1977–78	56	0.91	0.27	0.95	0.64	0.93	0.29	-0.46	–	–
1978–79	47	0.91	0.36	0.94	0.44	0.89	-0.23	-0.62	–	–
PC II Winter										
1975–76	23	0.15	0.45	-0.04	0.03	-0.40	0.87	0.70	–	–
1976–77	30	0.47	-0.03	0.78	0.65	0.92	0.11	-0.53	–	–
1977–78	25	0.30	0.77	0.10	0.63	0.08	0.79	0.75	–	–
1978–79	25	0.27	0.75	0.00	0.58	-0.03	0.67	0.61	–	–
PC I Summer										
1975	61	0.32	0.84	-0.05	0.72	0.37	–	–	0.91	0.85
1976	56	0.97	0.84	0.85	0.46	0.70	–	–	0.20	0.49
1977	63	0.98	0.87	0.92	0.63	0.76	–	–	0.14	0.30
1978	56	0.95	0.89	0.81	0.31	0.54	-0.13	-0.02	-0.54	0.51
PC II Summer										
1975	22	0.89	0.06	0.98	0.47	0.76	–	–	0.08	0.43
1976	20	0.12	-0.06	0.24	0.74	0.57	–	–	-0.88	0.48
1977	17	0.16	-0.06	0.27	0.71	0.60	–	–	-0.74	0.64
1978	19	0.27	-0.03	0.41	0.80	0.78	–	–	-0.66	0.77

loaded high on BDVGPC II the first winter, on BDVGPC III the second winter, and on BDVGPC I the last two winters (Table 4). More than 60 percent of the variance in PI, Volume, and FHD (VGPC I) was accounted for with a single BDVGPC the first three winters, but in the final winter BDVGPC I accounted for only 50 percent of the variance, while BDVGPC III accounted for an additional 19 percent. The gradient of increasing amounts of salt cedar and decreasing amounts of honey mesquite and shrubs (VGPC II) was accounted for by BDVGPC III the first winter and by BDVGPC II the last three winters. In the third winter, BDVGPC's II and V were required to account for two-thirds or more of the variance in VGPC II; VGPC III (PI and Volume 0-2) was accounted for by BDVGPC IV in the first and third winters, by BDVGPC V the second winter, and by BDVGPC III the final winter (Table 4).

More than 80 percent of VGPC IV (patchiness and volume at intermediate levels and shrubs and honey mesquite the second winter) was accounted for by BDVGPC V the first winter and by BDVGPC IV the second winter. There were only 3 VGPC's the third winter. In the final winter, BDVGPC's I, II and IV, collectively, accounted for about 83 percent of the variance in shrubs and honey mesquite (VGPC IV).

In summer, PI, Volume and FHD (VGPC I) were best accounted for by BDVGPC I (Table 4). VGPC II (the shrub and honey mesquite to salt cedar gradient) loaded highest on BDVGPC IV each summer except 1976. In the first summer, Volume and PI at low levels (VGPC III) loaded similarly on BDVGPC III and V. In the last three summers, they loaded on BDVGPC III twice and on BDVGPC II once. VGPC IV (PI and Volume at intermediate levels) loaded on BDVGPC III the first summer. VGPC IV (shrubs and honey mesquite) loaded on BDVGPC V the second and fourth summers. It was not present the third summer.

The relationship between BDVGPC's and VGPC's was closer (mean high loading larger) in winter than in summer for 3 of the 4 VGPC's. Only salt cedar (VGPC II) loaded as high, on the average, on a single BDVGPC during both seasons. This suggests that birds are more closely associated with the independent elements found in the vegetation in winter than in summer. Most studies reported in the literature summarize relationships between summer (breeding) populations and their response to the vegetation. Our vegetation-bird species data indicate that vegetation-bird species relationships in winter may be as important, or even more important, as in the breeding season. This can be investigated further by examining the relationship between the independent trend in the bird community (the original BDPC's) and the components when the bird and vegetation variables are combined.

In winter, total species, visiting insectivore species, and insectivore densities (BDPC I) were accounted for best by BDVGPC I (Table 5). The other gradient in the bird community structure (BDPC II) were considerably divided among the BDVGPC's. In summer, insectivores (BDPC I) loaded highest on BDVGPC II for the first three summers and on BDVGPC III for the final summer (Table 6). Quail and doves (BDPC II) loaded high on BDVGPC I during the first summer, but in subsequent years were considerably divided among the BDVGPC's (Table 6)

Table 4. Relationship between vegetation principal components (PC) and the vegetation on vegetation-avian principal component axes.

Season and year	BDVGPC	Percent of variance of original vegetation PC's accounted for I	II	III	IV	Percent of total BDVGPC variance accounted for
Winter						
1975-76	I	6.6	2.9	0.3	0.4	35
	II	63.8	5.2	1.8	1.7	19
	III	0.9	70.6	1.1	0.7	13
	IV	6.3	0.4	82.1	0.0	11
	V	10.7	0.3	4.4	90.8	8
Total		88.3	79.4	89.7	93.6	86
1976-77	I	5.8	7.3	0.2	1.3	34
	II	2.0	67.0	4.4	0.1	27
	III	65.8	4.6	3.7	2.3	12
	IV	6.5	5.7	1.2	83.7	8
	V	9.5	1.9	76.6	0.4	7
Total		89.6	86.5	86.1	87.8	88
1977-78	I	64.0	4.3	0.2	--	35
	II	2.0	51.0	0.6	--	26
	III	7.3	3.8	1.2	--	13
	IV	10.6	0.9	84.5	--	8
	V	6.1	28.5	1.0	--	6
Total		90.0	88.5	87.5	--	88
1978-79	I	50.4	0.6	4.7	13.9	37
	II	1.4	81.7	2.3	18.4	19
	III	19.2	0.4	82.5	0.4	16
	IV	2.1	2.0	1.6	50.3	9
Total		73.1	84.7	91.1	83.0	81
Mean high loading		61.0	67.6	81.4	74.9	
Summer						
1975	I	63.8	5.3	0.2	0.5	43
	II	3.6	1.4	11.6	13.2	16
	III	11.5	2.1	33.9	74.3	13
	IV	1.0	70.3	2.4	2.3	9
	V	8.0	1.6	38.8	0.4	6
Total		87.9	80.7	86.9	90.7	87
1976	I	37.7	1.8	5.1	8.6	42
	II	19.2	2.4	3.3	9.3	15
	III	1.0	5.5	62.5	6.1	11
	IV	28.8	2.5	1.3	8.1	9
	V	0.6	62.2	6.3	48.2	7
	VI	12.4	9.8	4.1	0.1	5
Total		99.7	84.2	82.6	80.4	89
1977	I	54.8	2.8	3.5	--	47
	II	13.6	3.5	0.4	--	15
	III	9.1	1.4	79.3	--	13
	IV	6.2	54.3	1.1	--	8
	V	4.9	18.9	0.0	--	5
Total		88.6	80.9	84.3	--	88
1978	I	51.7	0.8	19.4	0.9	46
	II	11.2	1.1	66.3	1.6	15
	III	11.6	0.0	0.3	3.9	11
	IV	3.1	84.0	1.4	10.1	8
	V	8.6	0.2	3.6	65.0	7
Total		86.2	86.1	91.0	81.5	87
Mean high loading		52.0	67.7	61.7	62.5	

Table 5. Relationships between principal components for birds, vegetation and bird and vegetation variables combined in winter.

Year	BDVGPC	Percent of variance in original BDPC's accounted for I	II	VGPC most similar to BDVGPC
1975-76	I	65	15	I
	II	13	19	I
	III	4	44	II
	IV	2	1	III
	V	3	2	IV
Total		87	81	
1976-77	I	45	30	I
	II	17	21	II
	III	5	28	I
	IV	21	5	IV
	V	1	2	III
Total		89	86	
1977-78	I	64	3	I
	II	5	20	II
	III	20	41	I
	IV	1	3	III
	V	2	16	II
Total		92	83	
1978-79	I	77	19	I
	II	4	14	II
	III	1	5	III
	IV	4	33	IV
Total		86	71	
Mean high loading		62.8	37.0	

Table 6. Relationships between principal components for birds, vegetation, and bird and vegetation variables combined in summer.

Year	BDVGPC	Percent of variance in original BDPC's accounted for I	II	VGPC most similar to BDVGPC
1975	I	8	63	I
	II	63	15	IV
	III	3	1	IV
	IV	3	2	II
	V	10	7	III
Total		87	88	
1976	I	9	25	I
	II	59	9	I
	III	2	22	III
	IV	7	10	I
	V	3	5	II
	VI	13	12	I
Total		93	83	
1977	I	11	35	I
	II	75	16	II
	III	3	21	III
	IV	2	5	II
	V	0	11	II
Total		91	87	
1978	I	8	21	I
	II	2	31	III
	III	74	11	I
	IV	1	8	II
	V	5	18	IV
Total		90	89	
Mean high loading		67.8	38.4	

Table 7. Correlations between independent avian variables (BDPC's) and independent vegetation variables (BGPC's). Key: SPPRI - species of permanent resident insectivores; DPRI - density of permanent resident insectivores; SPVI - species of visiting insectivores; DVI - density of visiting insectivores.

Season and year	BDPC	Associated insectivore variables	Correlation with VGPC	R(r)	$R^2(r^2)$	P
Winter						
1975-76	I	All insectivore variables	I	0.52	0.27	<0.05
1976-77	I	Total species, SPPRI, DPRI (26%)	I + II	0.72	0.51	<0.005
	II	SPVI,DVI,DPRI (43%)	I	0.57	0.32	<0.02
1977-78	I	Total species, SPVI, DVI, DPRI(41%)	I	0.74	0.54	<0.005
	II	DPRI (40%), SPPRI	II	0.69	0.48	<0.005
1978-79	I	SPVI, DVI	I	0.66	0.44	<0.005
	II	SPPRI, DPRI	II + IV	0.59	0.35	<0.025
Summer						
1975	I	SPPRI, DPRI	III	0.57	0.32	<0.02
	II	SPVI, DVI	I	0.84	0.71	<0.001
1976	I	Total species, SPPRI, SPVI, DVI	I	0.46	0.21	<0.05
	II	DPRI	I + III	0.70	0.49	<0.005
1977	I	Total species, SPPRI, SPVI, DVI, DPRI (37%)	I + III	0.42	0.16	NS
	II	DPRI (46%)	I + II	0.75	0.56	<0.005
1978	I	Total species, SPPRI (38%), SPVI, DPRI	I	0.50	0.25	<0.05
	II	SPPRI	I + II	0.68	0.47	<0.005

Both BDPC's were significantly correlated with VGPC's each winter. Insectivores (BDPC I) were positively associated with volume, patchiness and FHD (VGPC I) the first winter. In the second winter, the addition of VGPC II (high salt cedar, low honey mesquite), which was negatively associated with the variables associated with insectivores (BDPC I, Table 7), improved the correlation and retained statistical significance ($P < 0.005$). Permanent resident insectivores (BDPC II) were correlated with vegetation (VGPC II) during the third winter and with VGPC II and IV the fourth winter. In these cases it indicated that they were lower in densities and diversities where cottonwood-willow were present and were higher where shrubs and honey mesquite were present.

In winter, seedeaters and fruiteaters were associated negatively with VGPC II (abundant salt cedar, few shrubs, and little honey mesquite) every year (Table 8), indicating that these groups avoid salt cedar and are found in areas with shrubs and/or honey mesquite. In the case of fruiteaters, the attraction is mistletoe, but mistletoe in the lower Colorado River Valley parasitizes honey mesquite far more extensively than other plant species (Anderson and Ohmart 1978).

Table 8. Correlations between fruiteaters and seedeaters in winter and doves and quail in summer with the vegetation principal components

	Principal components		Correlation		
Year	Birds	Vegetation	R(r)	$R^2(r^2)$	P
Winter					
1975-76	II	I + II	0.70	0.49	<0.001
1976-77	I	I + II	0.72	0.51	<0.001
1977-78	II	II	-0.69	0.48	<0.001
1978-79	II	II + IV	0.59	0.35	<0.025
Summer					
1975	I	I	0.57	0.32	<0.01
1976	II[a]	I + III	0.70	0.49	<0.005
1977	I[a]	I + II	0.75	0.56	<0.005
1978	I	I	0.50	0.25	<0.05

[a]Doves positive, quail negative.

In summer 1975, permanent resident densities and diversities (BDPC I) were correlated with patchiness and volume at low levels (VGPC III) (Table 7). In subsequent years, BDPC I was more complex in that visitors were also represented on it. In these years Volume, PI and FHD (VGPC I) were the most important vegetation factors, but in the third year, even though salt cedar added positively to the correlation, the 2 VGPC's combined did not correlate significantly ($P > 0.05$) with insectivore densities and diversities (BDPC I). BDPC II varied considerably from year to year. In the first summer it included densities and diversities of visiting species and correlated signigicantly with VGPC I. The next two summers it included densities of permanent residents and was associated with Volume, PI and FHD (VGPC I), plus either VGPC III [illegible]

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were associated with salt cedar (VGPC II) five times and the contribution was negative four times. This supports findings presented by Cohan et al. (1978) that salt cedar has low use values for permanent residents. Visiting insectivores were not associated in any significant correlation with salt cedar, either positively or negatively.

In summer, BDPC I included densities of Gambel's Quail and doves and was correlated with VGPC I (volume, patchiness, FHD) (Table 8). In the second summer, doves were on BDPC II, which was correlated with VGPC I and III (volume and patchiness at low levels, respectively); Gambel's Quail were negatively associated with these vegetation parameters. The third summer, doves (on BDPC I) were significantly correlated with Volume, PI and FHD, and salt cedar (VGPC I and II, respectively), and in the final summer, they were exclusively correlated with VGPC I. In both years, quail were negatively associated with these factors. It appears then, at least in summer, that quail apparently avoid the vegetationally denser areas.

These analyses demonstrate that birds used the vegetation differently in summer and winter and that they were more strictly associated with vegetation structure in winter. Furthermore, permanent resident and visiting species tended to be more separated in winter than in summer. Although there were significant correlations in summer, they averaged lower and more vegetation variables were required. If habitat improvement plans are designed on the basis of data relative to bird-vegetation relationships collected only in summer, the plans might fail because the area might not be adequate for permanent residents or visitors, or both, in winter. This could lead to lower than expected use in summer. It is also clear that total foliage volume, horizontal patchiness, number of cottonwood-willow trees, and FHD (VGPC I) are all potentially important variables, because they were implicated in 17 of 23 cases (Tables7 and 8). In our coarse-grained analysis, we were not able to separate these factors. We are presently engaged in a finer-grained analysis designed to yield more information about the relative importance of these variables.

Seedeaters seemed to be associated with low, dense, shrubby vegetation (negative score on VGPC II and/or positive score on VGPC IV in the second and fourth winter), at least in winter. Permanent residents were also associated with this type of vegetation fairly consistently. Doves in summer were associated with dense, vertically and horizontally diverse vegetation, and quail with sparser vegetation.

With this information, predictions relative to avian use of areas can be made. With our data set we developed a predictive model and community revegetation designs which should possess high avian use values. Details of the designs have been presented elsewhere (Anderson et al. 1978, Anderson and Ohmart 1979). We began implementing the revegetation plans in 1977. Avian censusing has been conducted on a plot of approximately 40 ha since our initial work began. Trees and shrubs were planted (1977 and 1978) or have invaded, and the horizontal and vertical diversity of the vegetation has changed considerably in the past two years. Whether the bird densities and diversities have changed in response to changes in the vegetative makeup, in ways close to predictions, is of critical importance.

Test of the Predictions

We include data for summer and fall 1979 in our check of predictions. Characteristics of the vegetation in summer and early winter were quite different, with increases in volume and patchiness, and in the number of trees taller than 3 m (Table 9). Clearly, avian use of the area also changed, but these changes are not as important as whether the avian community responded according to predictions based on our model. To make this determination, we converted the avian and vegetation data from the revegetation plot to factor scores on the avian and vegetation PC's

Table 9. Changes in the vegetation and bird variables on the revegetation plot from summer to fall 1979.

Variables		Summer	Fall
Vegetation			
Vol.	0.0 - 0.6 m	0.522	0.717
	1.5 - 3.0	0.704	1.058
	4.5 - 6.0	0.006	0.006
	Total	1.232	1.403
PI	0.0 - 0.6 m	0.045	0.063
	1.5 - 3.0	0.008	0.013
	Total	0.053	0.112
FHD		0.278	0.272
Cottonwood-willow >3 m/ha		0.0	12.1
Salt cedar >3 m/ha		0.6	0.6
Shrubs/ha		190.0	160.0
Honey mesquite with mistletoe		0.0	0.0
Proportion salt cedar (%)		41.0	5.0
Avian			
Total species/40 ha		17.0	33.0
Number of species/40 ha			
	Visiting insectivores	6.0	12.0
	Permanent resident insectivores	12.0	8.0
Density/40 ha			
	Visiting insectivores	15.0	23.0
	Permanent resident insectivores	9.0	45.0
	Seedeaters	21.0	512.0

Table 10. Predicted and observed factor scores for avian principal components on a revegetation site.

	Factor scores			
	BDPC I		BDPC II	
Season	Predicted	Observed	Predicted	Observed
Summer 1979	-0.79	-0.10	-0.40	-2.45
Fall 1979	-0.89	-0.56	1.02	1.04

using 1978 vegetation data and summer 1978 and winter 1978-79 avian data. Regression equations using PC factor score coefficents were used to make predictions (Table 9) of what the factor scores should be on the revegetation plot. The analysis revealed that for visiting insectivores (BDPC I) the observed factor scores were larger than expected (Table 10). In summer, the score on BDPC II was much lower than expected; this is due primarily to low densities and diversities of permanent resident insectivores. The fact that there was intensive revegetation activity on the site may have been a significant factor, but if so, the reason that birds on BDPC I were not affected is not clear. From a biological viewpoint, however, it seems reasonable to expect the more mobile transient population to find a new area first. Permanent residents are busy nesting in more preferred areas at this time. In the post-breeding season the young disperse and should occupy the new area. Our observations were in accord with this. In fall, seedeaters and permanent resident insectivores (BDPC II) were almost exactly the same as the expected value. Thus for 3 of the 4 predictions, the observed values did not differ significantly from predicted.

In fall, the revegetation site ranked below average (relative to other vegetation types along the lower Colorado River) for visiting insectivores (BDPC I), but was near the top in value (Fig. 2) to birds associated with BDPC II (primarily seedeaters). In summer, the revegetation plot ranked last for BDPC II but somewhat higher for BDPC I.

We stated that we were unable to separate total Volume, FHD, PI, and CW and so we were unable to determine if all 4 of these variables were important or whether a single one among them was the most important variable. The revegetation plot provides some clues. For example, the mean Volume (1.6 ± 0.1) and mean FHD (0.88 ± 0.05) for the 23 vegetation types were substantially larger than the Volume (1.4) and FHD (0.27) on the revegetation site in fall. But the mean PI for the 23 vegetation types (0.09) was 22 percent smaller than that found on the revegetation site (0.11). Log_{10} of the mean number of CW/0.4 ha (0.5) was smaller than for that of CW on the revegetation site (0.7). Although PI and CW are still not separated, the early indications are that one or both of these two variables are more important than Volume or FHD in determining the number of species occurring in an area for fall since total species observed (33) was larger than average (29) for the 23 vegetation types in fall. If Volume and FHD were the most important variables, the number of species on the revegetation plot would be expected to be lower than average.

SUMMARY

Preliminary efforts (2 years along) to develop high-quality riparian habitats for birds indicate that it is feasible. Considerations in habitat design should be given to the needs of both wintering and breeding species. Our data demonstrate that birds used the vegetation differently in summer than in winter and that they were more strictly associated with vegetation structure in winter, and even more so in harsh winters.

Predictions of avian use in the newly developed community were not significantly different from empirical values. Subsequent monitoring of bird use on the revegetation site will reveal the full potential of the effort. Continued monitoring and additional data should allow the resolution of the importance of foliage volume, foliage height diversity, patchiness and cottonwood-willow to birds in southwestern riparian habitat revegetation efforts.

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A REVIEW OF THE EFFECTS OF OFF-ROAD VEHICLES ON BIRDS AND OTHER VERTEBRATES

Kristin H. Berry

California Desert Plan Program
U.S. Bureau of Land Management
Riverside, California

ABSTRACT

A review of the literature on the effects of off-road vehicles (ORVs) on birds revealed five papers, only one of which covered the subject in depth. There are several additional papers on impacts of ORVs on fishes, amphibians, reptiles and mammals, most of which deal with species of the arid Southwest. Almost without exception, analyses of the data reveal that ORV use has significant negative impacts and can reduce numbers, diversity, and biomass of vertebrates. The degree of impact depends upon amount and intensity of ORV use, habitat type, and sensitivity of the species. The literature on effects of ORVs on soils and vegetation--major wildlife habitat components--and on related topics such as erodibility of soils, rates of erosion, and revegetation, is much more extensive. Information from such studies infer the kinds of impacts that can occur to birds and other vertebrates.

INTRODUCTION

During the last fifteen years, there has been considerable growth of off-road ehicle (ORV) activity, particularly of 4-wheel vehicles, motorcycles, and snow-obiles on both public and private lands. The Council on Environmental Quality 1979) views the off-road vehicle problem as one of the most serious public land-se problems today. Several review papers have covered a number of ORV topics Baldwin and Stoddard 1973, Luckenbach 1975). There are also several bibliogra-hies (Bury 1976, Bury et al. 1976, Lime and Leatherberry 1974, Lodico 1973, Webb nd Wilshire 1978).

Much of the latest research concerning ORV impacts on animals is not in the pen literature; it exists in the form of contract reports to agencies, agency technical or "draft" reports, undergraduate or graduate student papers, or papers

"in preparation" or "in press." Many of those involved in research on ORV-related effects on biological or physical resources circulate unpublished reports or papers among themselves and interested parties. Eventually many manuscripts will be published in the open literature; unfortunately some will not and for others the time until publication is two to four years hence.

The purpose of this review paper is to summarize the available information for ORV impacts on birds and to review briefly the kinds of existing information on other vertebrate species and their habitats. The review is by no means exhaustive; recently completed and relatively inaccessible documents are emphasized intentionally. Sources for all unpublished papers and reports are provided in the Literature Cited section.

This paper is subdivided into three parts: effects of ORVs on birds, effects of ORVs on other vertebrates, and effects of ORVs on wildlife habitats.

EFFECTS OF OFF-ROAD VEHICLES ON BIRDS

Studies and Observations in Four General Habitats

Studies of impacts of ORVs on birds have been limited primarily to desert scrub, washes and microphyll woodlands, and riparian habitats in the Mojave and Colorado Deserts of California (Bury et al. 1977, Luckenbach 1978, Weinstein 1978). There are a few observations of ORV impacts on turkeys in an oak-hickory hardwood forest (McEwen 1978) and Prairie Falcons in desert scrub (Harmata et al. 1978).

DESERT SCRUB HABITATS

The first published study on ORV effects on birds (Bury et al. 1977) dealt with impacts of motorcycle and 4-wheel vehicles on vertebrates creosote bush (Larrea tridentata) communities at seven study sites in the central Mojave Desert. Study plots consisted of controls (relatively free of ORV tracks), moderately used, heavily used, and pit areas (camping and ORV staging areas with most shrubs and ground cover absent or pulverized). At one site (4 ha plots), the control plot had five times the number of breeding pairs and ten times the biomass compared with the moderately used plots. The pit area had no birds. In 1975 on larger 40 ha plots at new locations, the differences in breeding birds were not as marked: two times the number of pairs and species and 1.7 times the biomass on the controls compared with moderately used sites.

Desert scrub communities, such as creosote, saltbush (Atriplex spp.), and shadscale (A. confertifolia, Grayia spinosa, Eurotia lanata and numerous others), generally have low structural diversity and cover of vegetation. They support limited numbers of breeding bird species, with pairs widely spaced. Recent breeding bird studies on four desert scrub plots in the same general area as the Bury et al. (1977) study averaged 31 (range 18 to 56) breeding and 74 (range 26 to 178) wintering birds per 40 hectares (ha) (Dock 1978, 1979; Landry 1978a, 1978b. 1979a, 1979b, 1979c, 1979d). There were an average of four breeding and nine winter species for the sites.

Typical species living and nesting in desert scrub communities are: Roadrunner (Geococcyx californianus); Burrowing Owl (Athene cunicularia); Lesser Nighthawk (Chordeiles acutipennis); Horned Lark (Eremophila alpestris); LeConte's Thrasher (Toxostoma lecontei); Loggerhead Shrike (Lanius ludovicianus); House Finch (Carpodacus mexicanus) and Black-throated (Amphispiza bilineata), Sage (Amphispiza belli),

and Brewer's Sparrows (Spizella breweri). The plot sizes in the Bury et al. (1977), Dock (1978, 1979), and Landry (1978a, 1978b, 1979a, 1979b, 1979c, 1979d) studies were about 40 ha or less and appeared to be too small to adequately census all breeding or wintering species found in the habitats. However, the trends ahown by the Bury et al. (1977) studies for ORV impacts on birds are none the less valid.

In addition to the more typical species, there are "raptors," such as Turkey Vultures (Cathartes aura), Red-tailed Hawks (Buteo jamaicensis), Golden Eagles (Aquila chrysaetos), Prairie Falcons (Falco mexicanus), Great Horned Owls (Bubo virginianus), and Ravens (Corvus corax). These species nest in nearby cliffs and rock outcrops, and forage in the valleys and slopes with low scrub vegetation. They can be affected by ORV use through: disturbance to nest sites; loss of such prey species as lizards, desert tortoises, small birds, and mammals; and disturbance to foraging behavior. Disturbance at nest sites by ORVs and to foraging behavior has been documented for Prairie Falcons (Harmata et al. 1978). There are several accounts of declines for prey species in the Mojave Desert due to ORV impacts. Busack and Bury (1974) studied five species of lizards in heavy, moderate, and no use areas (relatively free of ORV tracks) in Dove Springs Canyon. They found reductions in both numbers and biomass in the plots with moderate and heavy ORV use (one species in the heavy use vs. five in the no use; 6.4 g/ha biomass in the heavy use vs. 509.9 g/ha biomass in the no use). Findings for lizards were similar in the Bury et al. (1977) report. Bury (1978a) and Berry and Nicholson (1979) also noted declines of desert tortoises in several ORV use areas in the western Mojave Desert.

Several species of small mammals showed reductions in numbers, biomass, and diversity in ORV use areas. Byrne (1973), using sites in Dove Springs Canyon similar to those in the Busack and Bury (1974) study, reported that density and diversity of small mammals was significantly lower on ORV-disturbed sites. Bury et. al. (1977) had similar findings.

The Bury et al. (1977) study, in summarizing impacts on all species of small vertebrates examined, found that numbers of individuals in heavily used and pit areas were 55 and 20 percent, respectively, of those present in undisturbed sites. Biomass estimates were even lower (23 and 17 percent, respectively).

These significant reductions in small animals easily could have measurable impacts on raptor foraging success and, ultimately, on productivity. Garrett and Mitchell (1973) and Boyce (1977) reported declining Prairie Falcon populations in the California deserts. Harmata et al. (1978), after examining productivity in ten pairs of Prairie Falcons in the western Mojave Desert, suggested their findings of productivity (1.2 young per nesting attempt) were low and indicative of declines.

like catclaw (Acacia greggii), mesquite (Prosopis spp.), desert lavender (Hyptis emoryi), and chuparosa (Beloperone californica); and many smaller shrubs. These washes are highly productive for birds and other species. The large shrubs and trees provide added perching nesting, foraging, and cover sites that are not present in the low scrub habitat types.

Several recent breeding and winter bird surveys verified that microphyll woodlands support much higher numbers and kinds of birds than do surrounding desert scrub habitats. Breeding bird numbers for seven wash study sites in the Colorado Desert had seven times the numbers of species and over 45 times the total number of individuals than did a similar number of plots in surrounding low scrub habitat with no overstory (U.S. Bureau of Land Management field notes; Daniels and Boyd 1979a, 1979b; Foster and Johnston 1979a; Franzreb 1978; Johnston and Foster 1979a; Tomoff 1977). Winter bird populations were over eight times as high in washes than in surrounding low desert scrub (Daniels 1979a, 1979b; Foster and Johnston 1979b; Henderson 1979; Johnston and Foster 1979b; Tomoff 1979a, 1979b, 1979c; Tomoff and Hecker 1979; Jones 1979, Jones and Clark 1979, Jones and Garrett 1979, Jones et al. 1979).

Findings were similar for washes in the Mojave Desert versus adjacent open desert communities. Winter bird densities were 50 to 60 times higher and numbers of species eight times higher in a catclaw-rabbitbrush (Chrysothamnum paniculatus) wash than in surrounding open desert (Remsen et al. 1976a, 1976b). Breeding bird densities were 15 times higher with six times the number of species (Kubik and Remsen 1977a, 1977b).

The higher densities and diversities of bird populations in washes is highly significant in terms of ORV activity. Washes are very limited in terms of overall acreage in the Southwest as compared with many other habitat types; in the California deserts, many are open to unrestricted ORV activity.

RIPARIAN

Weinstein (1978) undertook the most intensive and detailed study of ORV impacts on birds to date. He examined the effects of ORVs and general recreation on the avifauna of riparian habitats in Afton Canyon, which is part of the Mojave River in the central Mojave Desert, California. Afton Canyon has a number of distinct bird habitats: marshes, open water, meadows of salt grass and Yerba Mansa, willows, tamarisk groves, and mesquite. A campground established in 1968 gradually became the focus for ORV-oriented recreationists with 4-wheel vehicles, trail bikes, and dune buggies. The campground and surrounding areas have received heavy impacts.

they were not. On days with heavy ORV visitor use, the high-use plot had significantly fewer and the low-use plot significantly more birds.

Ten species were selected for more detailed discriminate analyses (Weinstein 1978). These were the American Kestrel (Falco sparverius), Mourning Dove (Zenaida macroura), Common Flicker (Colaptes auratus), Say's Phoebe (Sayornis saya), Western Meadowlark (Sturnella neglecta), Verdin (Auripatus flaviceps), House Finch, White crowned Sparrow (Zonotrichia leucophrys), and Cedar Waxwing (Bombycilla cedrorum). Canonical correlations showed marked tendencies for most of the ten species to move away from ORV use areas, as much as 0.8 to 3.2 km, to flush more readily, or to perch in dense thorny bushes. Of all species tested, Mourning Doves showed the strongest response to ORVs and people and moved far away.

Off-road Vehicle-related Problems

The Weinstein (1978) study documented a number of related ORV problems suspected or described for other classes of vertebrates. Off-road recreationists broke campground regulations, vehicle use regulations, and federal and state wildlife protection laws. Weinstein (1978) states:

> Although shooting is prohibited within one-half mile of the campground, the vast majority occurs within a hundred yards of it, or actually within it...The sight of a person sitting in a dune buggy, rifle in one hand, can of beer in the other, is a common sight...The litter of spent shells can be seen nearly everywhere, and many nongame species can be found dead, shot after a weekend of "target" shooting.

In violation of state laws visitors cut down mesquite trees shading picnic tables for firewood. They often leave litter. Weinstein (1978) noted the importance of mesquite for cover and suspected it was being removed at higher than replacement rates. Campfires were established outside the campground, and during the summer portion of the study period, there were four brush fires, three from campfires.

Signs specifying vehicle use only on established roads were ignored (Weinstein 1978). New roads and trails were continually formed through meadows and willow groves, along streamside vegetation, and in washes. One of Weinstein's closing remarks is thought provoking:

Noise

There are few papers on the effects of ORV noise on birds. Marler et al. (1973) demonstrated that loud continuous sounds could permanently damage the hearing of birds. They studied canaries hatched and raised under 95 to 100 decibels (db) noise and found partial deafness, with longer exposure causing greater deficits. Hearing losses were greatest to the high frequency sensitivities. The authors suggested further research on potential retardation of reproductive development from noise, effects of noise on song development, and effects of partial deafness on the fine structure of song.

Luckenbach (1975, 1978) and Weinstein (1978) have suggested that high levels of ORV noise could interfere with bird communication. Birds are generally highly vocal and communicate through songs and calls. During the breeding season, males maintain territories through song and at the same time court females. Calls serve a number of functions: recognition between mates and young, warnings, recognition signals, maintaining flocks, etc.

Weinstein (1978), in the study described earlier on ORV impacts on birds of desert riparian habitats, related that "birds were observed...to fly at the sound of the approach of vehicles, even if vehicles were at a considerable distance, and if they were out of sight." Birds were induced to abandon concealing vegetation and fly an estimated 0.8 to 3.2 km or more from the noise. The increased susceptibility to flushing and to flee the area could result in disruption of territories, decreased ability to feed young or defend the nest from predators, and increased vulnerability to predation on the adults.

Harmata et al. (1978) studied several pairs of breeding Prairie Falcons in the western Mojave Desert, a region regularly used by ORV recreationists. Their findings on impacts of ORV noise are intermingled with other human-related noise sources. The researchers reported that "sudden loud noises generally disturb Prairie Falcons" and that "extended periods of loudness near the eyrie may totally disrupt breeding behavior." An incubating female responded to the sound of motorcycles 800 m away. The falcon stood up as the noise reached a maximum and settled down as noise faded away. Falcons were flushed or moved in the eyrie when doors were slammed on a vehicle 100 to 150 m from the eyrie. In one case, incubation was disrupted when people camped and fired guns 50 m below one of the study eyries. Although the incident was not observed, the researchers saw normal incubation on April 12 and returned two days later to find the eyrie abandoned with a new campfire ring and several spent rounds of ammunition. The female of this pair, after abandoning her eggs, spent weekends when vehicular traffic was heavy in a mountainous "primitive area away from any vehicles and away from some of her usual week-day flight areas.

McEwen (1978) cited several instances in which grazing turkey flocks in an oak-hickory hardwood forest were flushed by motorcycles traveling on a road 460 m away.

Noises other than from the vehicle itself often are associated with the ORV user and can be deleterious to birds. Gunshots can be a source of disturbance. An incubating female Prairie Falcon abruptly left her eyrie and remained about 1 km away in flight for 21 minutes when gunshots were fired on the opposite side of the rock pile supporting the eyrie (Harmata et al. 1978). The individuals doing the shooting were not visible to the falcon from the eyrie.

Although gunshots and ORVs were disruptive to Prairie Falcons, the high level noise and sonic booms of low flying jet aircraft and bombers caused no reaction (Harmata et al. 1978). Similarly Weinstein (1978) noted that trains did not disturb some birds but ORVs did. A pair of Say's Phoebes nesting under the tracks of a railroad trestle adjusted to the passage of 15 to 20 trains per day and were able to fledge two clutches. However, the phoebes flew at the approach of ORVs.

EFFECTS OF OFF-ROAD VEHICLES ON OTHER VERTEBRATES

Fishes and Amphibians

Adams (1975) found that hydrocarbons from snowmobile exhaust contaminated a Maine Lake through snow melts. The polluted water decreased stamina in brook trout fingerlings. Luckenbach (1978) pointed out the potential pollution problems for amphibians and other inhabitants of desert water sources from recreation vehicles.

Reptiles

Two studies on the effects of ORVs on lizards in the Mojave Desert revealed that moderate and heavy ORV use results in decreases in numbers, biomass, and diversity (Bury et al. 1977, Busack and Bury 1974). The reductions were greater in heavily used and pit or camping areas. In a study of the impacts of ORVs on lizards of the Imperial Dunes, Bury (1978b) found a twenty-fold reduction in the Colorado fringe-toed lizard on the ORV use plot compared with the control (no ORV use). Vollmer et al. (1976), in a short-term controlled experiment on the effects of light use of 4-wheel vehicles on desert scrub habitat, had no conclusive evidence of impacts on lizard populations.

There is information for ORV impacts on desert tortoises from several study sites in the Mojave and Colorado Desert (Bury 1978a, Berry and Nicholson 1979). Bury (1978b) reported marked reductions in heavily used ORV areas for both tortoises and actively used burrows. Berry and Nicholson (1978) have observed direct kills, degradation to habitat, and decline in numbers in lightly, moderately, and heavily-used ORV areas. Such impacts occur in both authorized and unauthorized ORV use areas.

Mammals

Several studies have been undertaken on the effects of ORVs on small mammals in the western Mojave Desert (Byrne 1973; Bury et al. 1977; Hicks et al. 1977; U.S. Bureau of Land Management 1975). These researchers reported declines in numbers and reductions in biomass and diversity under moderate to heavy ORV use or disturbance. In one project, study plots were established on the Barstow-Las Vegas motorcycle race course immediately after the race (U.S. Bureau of Land Management 1975). Evaluations of plots on the course versus the controls indicated a 90 percent decline in small mammals. One year later at the same area, Hicks et al. (1977) found eight times the density of rodents in the control plot compared with the plot on the course. There had been no races in the intervening period. The results of one study on the effects of light 4-wheel vehicle use on small mammals under a controlled situation were inconclusive (Vollmer et al. 1974).

There are three papers and one note with observations of ORV impacts on large game animals. Jorgensen (1974) found a 50 percent reduction of peninsular bighorn sheep use at a watering site when ORVs were in the vicinity. Hoover (1973) reported

instances of harassment of elk by ORVs and related declines. During a five-year monitoring study of ORV impacts at the Turkey Bay Off-Road Vehicle Area and elsewhere in the Land Between The Lakes recreation area, McEwen (1978) noted that there were no differences in the numbers of deer killed by hunters in the ORV use area compared with the rest of the recreation area. The habitat both inside the ORV area and elsewhere within the recreation area is oak-hickory hardwood forest. The ORV Monitor (1979) described how two coyotes were killed and a third injured by snowmobilers in the Potholes section of Grand Teton National Park, the one area in the National Park system open to cross-country snowmobiling. Two men pleaded guilty to "reckless" driving.

Noise

Recent research by Bondello et al. (1979) and Bondello and Brattstrom (1979a, 1979b) reveals the high sensitivity of wild animals other than birds to ORV sounds. Their studies are worthy of description here. Bondello and Brattstrom (1978a, 1978b) first reviewed the literature on the effects of noise on nonhuman vertebrates, then measured levels of natural and mechanized sounds in the California deserts. They selected three species of desert animals for studies on potential ORV noise impacts (Bondello et al. 1979), Bondello and Brattstrom (1979a, 1979b). The species--Couch's spadefoof toad (Scaphiopus couchi), the Mojave fringe-toed lizard (Uma Scoparia), and the desert kangaroo rat (Dipodomys deserti)--all live in quiet environments and are remarkably sensitive to certain frequencies of sounds. All suffered deleterious effects from exposure to ORV sounds.

The first study on Couch's spadefoot toad summarized life history and behavioral characteristics which made the species susceptible to ORV noise (Bondello and Brattstrom 1979a). There are a few relict populations of Couch's spadefoot toad in the deserts of southeastern California; populations exist in and adjacent to ORV use areas. This species is highly adapted for living in arid environments. Individuals spend most of the year 50 cm or more below ground, normally emerging only with summer thunderstorms to breed in temporary ponds. Normal emergence may be due to one or more acoustical stimuli associated with summer thundershowers, such as intense episodes of thunder and electric activity, high barometric pressures, high temperatures and high vapor pressure. However, when the toads are subjected to motorcycle sounds of 95 dBA (100 dBL), they respond by moving out of burrows to the surface. By misinterpreting ORV sounds as natural environmental cues, toad populations could be jeopardized. Off-road vehicle sounds induced the toads to emerge at the wrong season, in the absence of water. Under normal conditions, recently emerged toads are severely stressed from depletion of fat reserves and dehydration. They may be unable to rebuild themselves and survive in the weakened state until the appropriate environmental cues occur.

The second study was on the effects of dune buggy sounds on the Mojave fringe-toed lizard (Bondello et al. 1979). This species has a limited geographic range and lives only in wind-blown sands or dunes. It has a number of special adaptations for sand dwelling. Much of its habitat is used by ORVs. Bondello et al. (1979) surgically implanted electrodes in the telencephalic auditory region to monitor the auditory evoked response to known stimuli before and after exposure to dune buggy sounds of 95dBA (100 dBL). Actual hearing loss was recorded after only 500 seconds of exposure time. Even buried lizards could be exposed to high sound levels.

The importance of hearing in this species is probably related to food acquisition and predator avoidance (Bondello et al. 1979). Fringe-toed lizards feed on insects and are preyed upon by snakes and owls. Their prey and predators produce low intensity sounds, such as the movement of insects through debris, sliding of snake scales on sand, and the swooping of owls. Predator and prey sounds coincide with the maximum acoustical sensitivities of the lizards.

The extreme vulnerability of fringe-toed lizards to short durations of sounds is not typical of humans (Bondello et al. 1979). The Occupational Safety and Health Administration (OSHA) recommends that cumulative exposure of 95 dBA not exceed four hours. The loss of hearing in lizards with 500 seconds exposure indicates there may be profound differences in noise levels tolerable to wild animals as compared with the human ear.

In a third experiment, Bondello and Brattstrom (1979b) examined the effects of dune buggy sounds on desert kangaroo rats. Desert kangaroo rats, the most specialized of 13 species of kangaroo rats in California, are residents of wind-blown sands and dune systems. The genus of kangaroo rats, Dipodomys, has both highly specialized ears and central auditory system. Earlier experiments have demonstrated the abilities of kangaroo rats to detect low frequency, low intensity sounds of predators, such as the movements of sidewinders and screech owls. Bondello and Brattstrom (1979b) sought to determine the effects of dune buggy sounds on hearing of the rats through behavioral means. They noted that desert kangaroo rats exhibited a stereotypic response, sand kicking, to faint sounds of crawling sidewinders. The rats were able to detect the presence of the snake through acoustical means and were able to avoid coming within the striking range of the rattlesnake. When subjected to 500 seconds of dune buggy sounds at 95 dBA (100 dBL), hearing sensitivity was reduced to the point where the kangaroo rat came within striking range of the rattlesnake. Hearing sensitivity gradually recovered after 21 days.

EFFECTS OF OFF-ROAD VEHICLES ON WILDLIFE HABITATS

There are several components to wildlife habitat, the more important of which include soil, vegetation, moisture, air quality, and noise levels. Habitat provides cover, forage, nest sites, burrow sites, perches, roosts, water, and other features essential for the existence of all kinds of animal species.

While there is a paucity of reports on ORV effects on animals, there are numerous papers on ORV impacts on soils and vegetation in many different habitat types ranging from deserts to forests. The reader may wish to explore the many references on ORV impacts to soils and vegetation, as well as such related subjects as trampling, soil erodibility, and predictions on erosion rates and revegetation in the annotated bibliography of Webb and Wilshire (1978). Sparrow et al. (1978) reviewed the literature on short- and long-term impacts of ORVs in arctic and subarctic alpine tundra and other northern habitats. Such papers are useful in drawing inferences on potential ORV impacts to habitats of birds and other vertebrates. The following is a very abbreviated summary of some studies on soils and vegetation.

Soils

There are several studies of ORV impacts on soils in playas, salt marshes, sand dunes, desert scrub, grassland, chaparral, oak-grassland, oak-chaparral, and tundra (Davidson and Fox 1974; Gillette et al. 1980; Sparrow et al. 1978; Snyder et al. 1976; Webb 1978; Webb et al. 1978; Wilshire 1977; Wilshire and Nakata 1976, 1977;

Wilshire, Shipley, and Nakata 1978; Wilshire et al. 1978). General finding for one or more of these studies reveal that ORV use (motorcycles or 4-wheel use): 1) increases bulk density of soils to depths of 90 cm or more, 2) substantially increases surface strength for most soil types, 3) reduces soil moisture for most soil types, 4) greatly reduces infiltration rates, 5) reduces porosity and permeability of soils, 6) changes the insulating characteristics of soils, i.e., extending the diurnal temperature range, 7) reduces organic carbon content, 8) increases runoff, and 9) increases rates of erosion. Some authors have noted the spread of impacts to adjacent areas and postulated extended periods for recovery of soil and vegetation.

In most cases the extent and degree of impact depended on such factors as: type of vehicle, amount of use, type of soils, degree of slope, topography, and vegetation. The degree of impact was closely related to the amount of use. Damage in many areas of repeated use has been extensive (Snyder et al. 1976, Webb 1978, Wilshire 1977, Wilshire et al. 1978). Erosion rates calculated at one study site in Chabot Park in the San Francisco Bay region exceeded tolerance values set by the U.S. Department of Interior, U.S. Soil Conservation Service, and U.S. Department of Agriculture by factors of 30, 46, and 17, respectively (Wilshire et al. 1978).

Changes in soil characteristics in turn influence biological productivity. Webb et al. (1978) and Wilshire et al. (1978) discuss and summarize ORV impacts on productivity. They reported that growth of plants and germination of seeds can be affected by temperature changes. Webb et al. (1978) found that diurnal temperature fluctuations become more extreme to a depth of 12 cm. In summarizing the literature on the topic, Wilshire et al. (1978) noted that root extension and penetration could be impeded by changes in bulk density and compaction. Webb et al. (1978) also cited lower nutrient contents in soils exposed to vehicle impacts and suggested that changes in soil organic material and nutrient content could have an effect on revegetation and soil physical properties.

Vegetation

Studies of ORV effects on vegetation have been done in several habitat types, such as dunes (Brodhead and Godfrey 1977), grassland (Foresman et al. 1976, Webb et al. 1978, Wilshire et al. 1978), desert scrub (Davidson and Fox 1974, Bury et al. 1977, Lathrop 1978, Vollmer et al. 1976) tundra (Wooding and Sparrow 1978), oak-woodland and chaparral (Webb et al. 1978; Wilshire, Shipley and Nakata, 1978; Wilshire et al. 1978).

There are direct and indirect impacts to vegetation from the wheels as well as the vehicle itself from: crushing of stems, foliage root systems and seedlings; and uprooting of small plants. Through erosion, root systems can be undermined and trees toppled (Wilshire, Shipley and Nakata 1978). Vegetation can be buried by debris from eroded slopes and hillsides. Wilshire, Shipley and Nakata (1978) and Wilshire et al. (1978) noted that "four wheel vehicles are capable of opening trails through dense chaparral 4 m tall...and that...juniper and joshua trees more than 3 m tall have been destroyed by the direct impact of 4-wheel vehicles.

In summarizing general impacts to habitats, the authors noted above documented one or more of the following findings: 1) reduction in density of perennial plants, 2) reductions in cover of perennial shrubs, 3) reduction in diversity of perennials, 4) reduction in biomass, and 5) changes in annual plant production. As with soils, the degree of impact is dependent on the amount and intensity of ORV use, vegetation type, topography, etc.

SUMMARY

1. Off-road vehicle use has been identified by the Council on Environmental Quality as one of the most serious public land-use problems today.

2. Although there are few papers on the effects of ORVs on birds, existing data indicate that ORVs can have profound and highly significant negative impacts by reducing abundance, variety, and biomass. Species typical of desert scrub, microphyll woodland wash, riparian, and oak-hickory hardwood forest habitats were affected in one way or another. The riparian study by Weinstein (1978) was the most intensive.

3. Similar results were obtained in studies of other vertebrate species, particularly reptiles and small mammals. Numbers, diversity, and biomass were markedly reduced in most species exposed to moderate and intensive ORV use.

4. There are few observations on the effects of ORV noise on birds. Weinstein (1978) reported that ORV noise induced birds to abandon concealing vegetation and fly from 0.8 to 3.2 km away from the sound of approaching vehicles. Wild turkeys also fled at the approach of vehicles (McEwen 1978), and Prairie Falcons stood up in nest or flew from vehicles on occasion (Harmata et al. 1978).

   Intensive studies on the effects of ORV sounds on three species of vertebrates by Bondello et al. (1979) and Bondello and Brattstrom (1979a, 1979b) indicated high sensitivities to ORV noise. The hearing abilities of the desert kangaroo rat and Mojave fringe-toed lizard were damaged by ORV noise, and maladaptive behaviors were induced in Couch's spadefoot toad. If such studies were undertaken on wild birds, similar findings might be expected.

5. Other impacts to animal communities are associated with ORV users, such as illegal shooting, vandalism, and harassment.

6. There are far more papers on the effects of ORVs on two major habitat components of wildlife habitat--soils and vegetation. Studies of ORV use on soils indicate: substantially increased bulk densities and surface strengths; reductions in moisture, infiltration rates, porosity, and permeability of most soil types; changes insulating characteristics; decreased nutrient values; and increased runoff. Erosion rates can increase markedly, with mass wasting of soils far in excess of tolerance levels set by federal agencies.

   Changes in soil characteristics in turn influence biological productivity and ability of soils to support vegetation. Vegetation was also affected by ORV use. Density, cover, diversity, and biomass of perennial shrubs were reduced.

7. The extent of ORV impact depends on types of vehicle, amount and intensity of use, soil and vegetation type, degree of slope, and type of topography. Soil and vegetation types studied to date cannot withstand the mechanical abilities of the vehicles.

8. With information existing today, biologists and land-use managers should exhibit stringent precautions and restrictions in selection of areas for ORV use and in managing that use. Data gathered to date indicate that most wildlife species and habitats are highly sensitive to light, moderate, and heavy vehicle use and that major deleterious impacts can occur to ecosystems.

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RAPTOR MANAGEMENT--THE STATE OF THE ART IN 1980

Richard R. Olendorff

Endangered Species Coordinator
U.S. Bureau of Land Management
California State Office
2800 Cottage Way
Sacramento, California 95825

Robert S. Motroni

Wildlife Biologist
U.S. Bureau of Land Management
California State Office

Mayo W. Call

Avian Biologist
U.S. Bureau of Land Management
Denver Federal Center, Building 50
Denver, Colorado 80225

ABSTRACT

The techniques of raptor management underwent a decade of intensive research during the 1970s. Raptor conservation, including species protection and management, as well as habitat protection and management, now receives unprecedented attention stemming generally from the increasing interest in nongame wildlife. Highlights of the 1970s include: 1) captive breeding (which is now routine) of 726 Peregrine Falcons at three major facilities in North America, plus smaller successes at other facilities and with dozens of other species worldwide; 2) proof of the value of egg manipulations (such as artificial incubation of thin-shelled eggs and double-clutching) in creating extra birds for management purposes; 3) the testing and evaluation of several methods of introducing extra birds to the wild, including clutch augmentation, fostering, cross-fostering, and hacking (controlled release of nestlings); 4) the establishment of numerous special areas to provide direct protection of key raptor habitats; and 5) the proliferation of raptor habitat management projects, including artificial feeding programs for raptors, provision of artificial perches and nesting structures, and the development of new natural nest sites. Success

with many techniques during the 1970s exceeded most expectations. The 1980s should bring greater use of these techniques -- when and if (!) they are needed.

KEYWORDS: raptor management, raptor protection, captive breeding, egg manipulations, brood augmentation, fostering, cross-fostering, hacking, environmental assessment, special areas, habitat protection, land conversion, artificial feeding, artificial nest structures.

INTRODUCTION

Earlier in this conference reference was made to Aldo Leopold's statement about saving all of the pieces being prerequisite to intelligent tinkering. Until recently, raptor biologists have in fact been trying merely to save all the pieces, so that they could someday have the opportunity to do some intelligent tinkering. We are happy to report that most of the pieces with hooked beaks and sharp talons have been saved, at least for the foreseeable future, and that a fair amount of tinkering is already underway.

This paper is an update on the state of the art of raptor management at the beginning of the 1980s. It also gives credit to those raptor biologists, conservationists, falconers, and other interested persons both on this continent and abroad who have collaborated in a diverse yet organized manner. We are given reason for optimism about the future of most raptor populations because of 1) the individual initiatives of the persons cited herein, 2) the organization provided by the International Council for Bird Preservation, Raptor Research Foundation, Hawk Mountain Sanctuary Association, and the National Wildlife Federation's Raptor Information Center, and 3) the specialized group efforts of the Peregrine Fund, North American Falconers' Association, Canadian Wildlife Service, Chihuahuan Desert Research Institute, Santa Cruz Predatory Bird Research Group, Hawk Trust, Southwest Hawk Watch, National Audubon Society, Eagle Valley Environmentalists, numerous federal, state, and provincial agencies, and many others.

Because of the interest of these groups and the recent information explosion concerning nongame wildlife (Murphy 1978), the concept of raptor management grew tremendously during the decade of the 1970s. This is indicated by the numbers and dates of publications reviewed for the present paper (Figure 1). When the pertinent literature was first reviewed in early 1973 (Olendorff and Stoddart 1974), fewer than 140 titles were available. During the last seven years about 435 titles have been added for a total approaching 600.

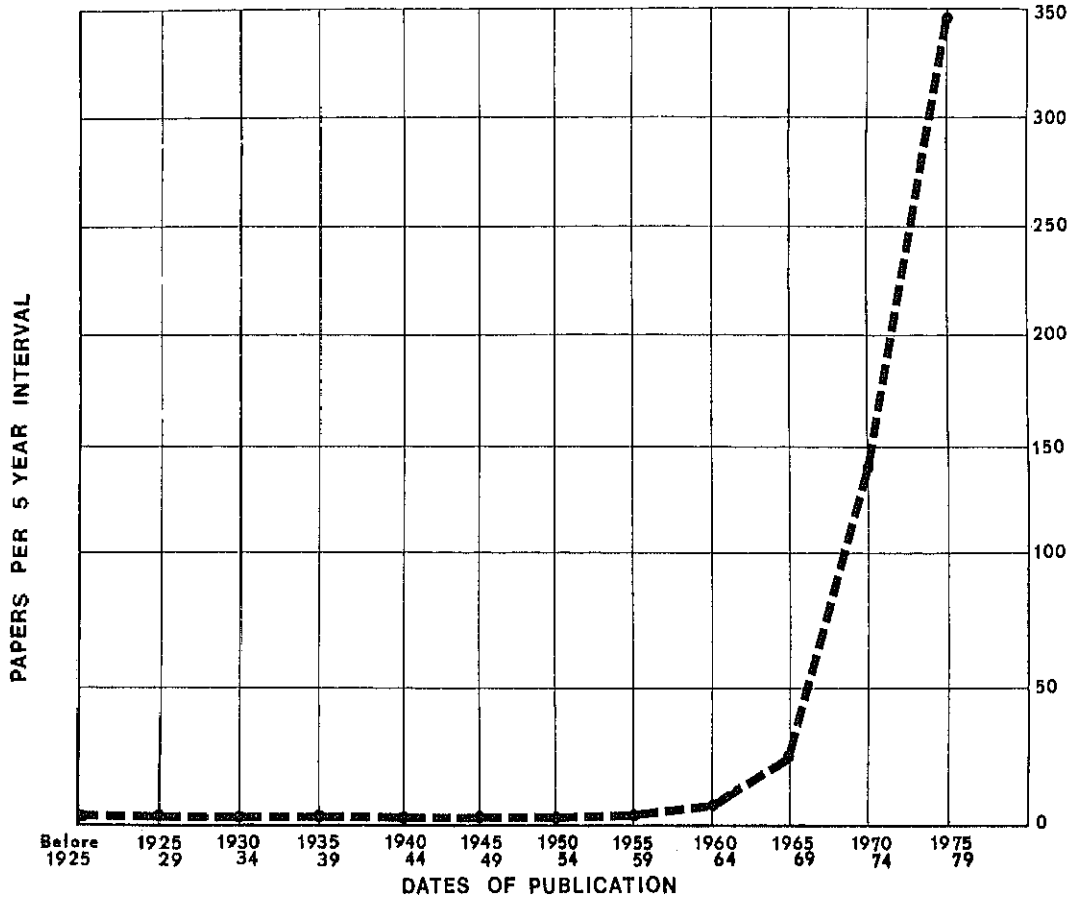

Figure 1.--The number of papers with direct raptor management implications published during each five-year period 1925-1979.

THE POTENTIAL FOR RAPTOR MANAGEMENT

l for management of raptor populations in western grasslands, / is much the same as in other habitats, has been summarized :ff and Stoddart 1974). This potential includes such things as :erent raptors use available nesting habitats differently; clump- :s where nest sites are abundant; use of man-made structures by ibstrates; the often low utilization of available prey resources; lon of large-scale, man-created changes in several key North . To this we can now add the success of recent raptor management l elsewhere in this paper.

:ion by raptors of large-scale land conversions points out the ire of some birds of prey and reminds us that far more raptor

management in this country has occurred inadvertently than has occurred purposefully--at least through the decade of the 1970s. Of particular note is the concentration around and extensive use of newly created reservoirs and dam outflows by Ospreys (Pandion haliaetus) and Bald Eagles (Haliaeetus leucocephalus) (e.g., Berger and Mueller 1969, Roberts 1969, Spencer 1976, Kennedy 1977b, Stumpf and Creighton 1977, Steenhof 1977, Henny 1977b, Henny et al. 1978a, 1978b). These species have reacted favorably to these changes and have pioneered the new habitats for nesting, feeding, and wintering. According to Lehman (1979), 70 percent of 95 Bald Eagle nest sites in California are associated with reservoirs.

Likewise with Ferruginous Hawks (Buteo regalis) and Swainson's Hawks (Buteo swainsoni) in the shortgrass prairie of northeastern Colorado (Olendorff and Stoddart 1974). In grasslands that were historically unbroken except by gallery forests and isolated springs, in 1970-1972, 44 of 45 Swainson's Hawk nest sites, 98 percent, were at abandoned farmsteads, ditches, windmills, or man-made ponds. Sixty-eight percent of the Ferruginous Hawks in historically unbroken grasslands were in man-created situations. A similar situation exists in parts of south-central Washington for Swainson's Hawks (Olendorff 1973), in the prairie provinces of Canada for Merlins (Falco columbarius) (Hodson 1976), and in the central United States for Mississippi Kites (Ictinia misisippiensis) (Parker 1975, Cranson 1975). Maser et al. (1979) discuss the value of man-made habitats to wildlife in general.

These examples do not mean that such large-scale, man-made changes were all good. To the contrary, what raptors gained, the ecosystem probably lost ten times over in ten different ways. These situations do hint, however, that purposeful management of these species may be possible.

Actually, "may be possible" is an understatement. The remainder of this paper deals with several major categories of the larger topic of raptor conservation. These include species and habitat protection (what we have learned from our efforts to save the pieces) and species and habitat management (what we have learned thus far by tinkering). Protection or "hands-off conservation" has been separated from management or "hands-on conservation," and species conservation is considered apart from habitat conservation. The most recent reviews of these topics are by Olendorff and Stoddart (1974), Cade (1974b), White (1974), and Snyder and Snyder (1975). Several conference proceedings are also germane: International Council on Bird Preservation (1964), Hickey (1969), Madsen (1973), Clement (1974), Hamerstrom et al. (1974), Ingram (1974, 1975, 1976), Ogden (1977), Temple (1978b), Chancellor (1977), Schaeffer and Ehlers (1978), Geer (1978), and Howard and Gore (1980).

SPECIES PROTECTION

Species protection includes the enactment of legislation, the promulgation of regulations, enforcement of these laws and regulations (including nest-site surveillance), and public education. The general legal status of raptors has been reviewed recently by Bond (1974), Hilton (1977), Conder (1977b), and Galushin (1977).

Three legislative or regulatory actions of the 1970s overshadow all others in importance to raptor protection. On March 10, 1972, the "Convention between the United States of America and the United Mexican States for the Protection of Migratory Birds and Game Animals" was expanded. This gave federal protection to all raptors under the Migratory Bird Treaty Act. Also in 1972, the use of DDT was banned in the United States, an action that was absolutely necessary to the survival of the Peregrine Falcon (Falco peregrinus), Bald Eagle, and Osprey. Almost two

years later, on December 28, 1973, Congress passed the Endangered Species Act of 1973, which has provided impetus--legal status as well as funding--to the endangered species conservation effort. The ramifications of these vital laws and regulations are felt almost daily by energy producers, land developers, the agricultural industry, and even individuals who interact with raptors in any way.

The enforcement of these laws and regulations, while there is room for improvement, is better than it has ever been. The National Wildlife Federation reward system ($500) for those who report Bald Eagle shootings, has been used 13 times between 1971 and January, 1980. In 1976 alone, 33 eagles were shot and then reported to the U.S. Fish and Wildlife Service. Nine people were convicted, fined up to $5,000, and given up to six months in jail (Schreiner and Senecal 1978).

One outgrowth of stepped up law enforcement is the Peregrine Falcon nest surveillance program in California, which has been directed by David L. Harlow (1977, 1978) and Douglas A. Boyce (1979) of the U.S. Fish and Wildlife Service. An eyrie warden program has been operating in Europe since about 1967 (Lindberg 1975, 1977). From 1967-1974, 19 Swedish eyries were given 24-hour surveillance. Twelve of these fledged young. In five eyries no eggs hatched; and two eyries were subjected to predation by mink or Eagle Owls (Bubo bubo).

In the United States, surveillance also started, though on a smaller scale, in 1967 and 1968 when Morro Rock, a prominent and well-publicized Peregrine eyrie on the California coast, was given 24-hour protection during the nesting season (McNulty 1972, Asrow 1977, Thelander 1978). This program was intermittent until Harlow took it over for the U.S. Fish and Wildlife Service in 1977. From 1977-1979 watches were maintained at 22 sites; 17 of these fledged young. Because of this comparatively high success rate at guarded eyries, the surveillance program is slated to continue into the 1980s.

SPECIES MANAGEMENT

Separate from species protection are two categories of species management: creating extra raptors for management purposes and introduction of extra birds to the wild. The numerous species management options involving captive breeding of raptors, introduction to the wild of eggs, young, and older birds, manipulation of wild populations, and the various combinations of these procedures are summarized in Figure 2. Processes shown nearest the center of the figure represent the captive regimen, while those around the periphery are natural (optimal) processes. At each major event in the life cycle (courtship, egg laying, hatching, fledging, and maturation) three major options are shown. Designs of nearly all pioneering and on-going raptor management research projects, as well as most conceivable avenues of future research on raptor species management, can be derived from this figure.

For example, in a hypothetical pair of captive adults, courtship (I--see Fig. 2) may be normal, but fertilization of eggs may be a problem. This can be solved by artificial insemination (IC) to get the laying of fertile eggs (II). It is now known that a period of incubation by either wild or captive adults (IIB) increases hatchability of artificially incubated (IIC) eggs. Artificial incubation may be desirable in order to double-clutch (recycle) the original pair. Once the eggs hatch (III) in the incubator, they might be hand reared (IIIC) until they are large downies at which time they could be fostered to a nest and reared by wild

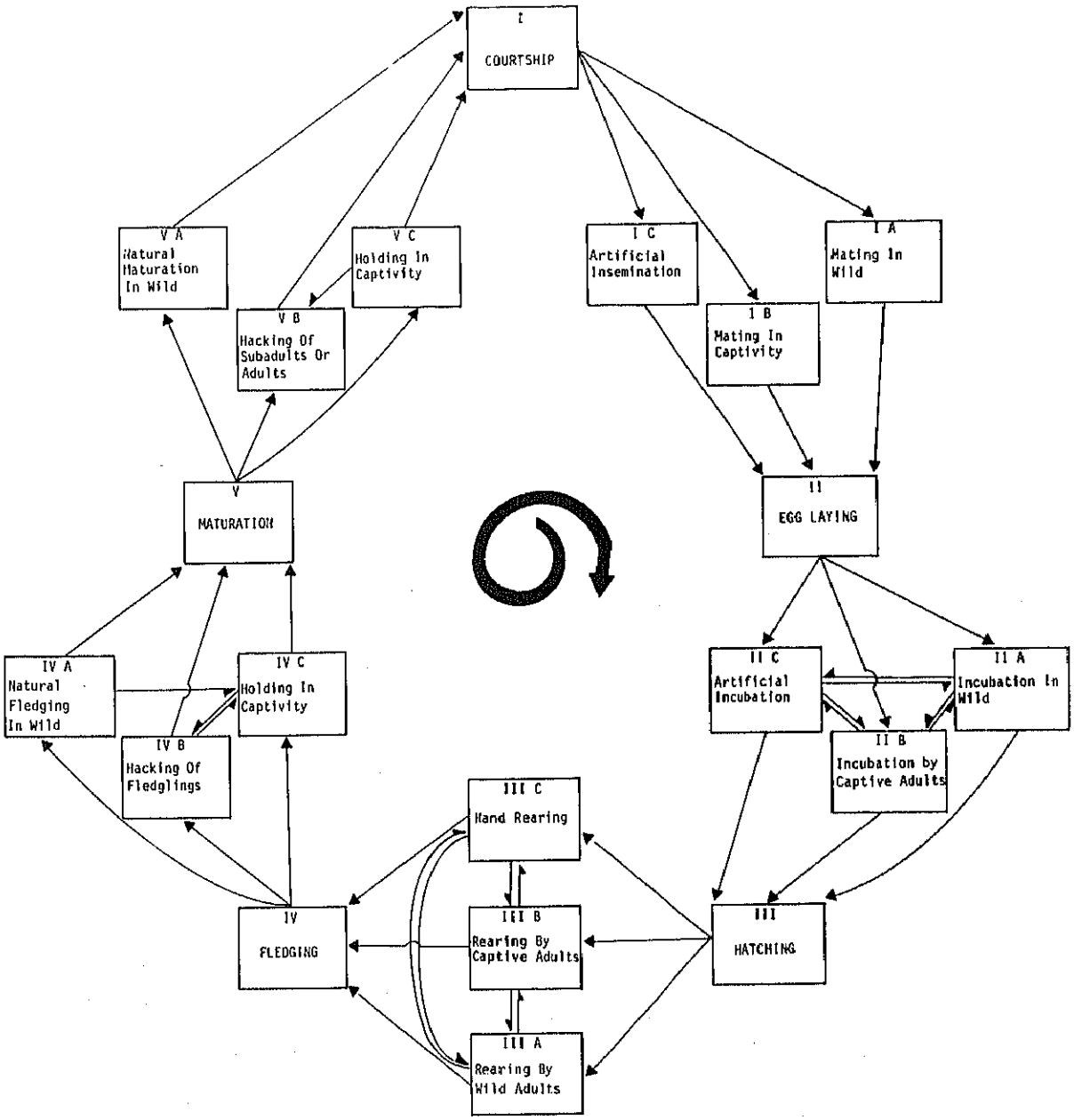

Figure 2.--Species management options involving captive breeding of raptors, introduction of birds to the wild, and manipulation of wild populations. See text.

adults (IIIA). Once fledged naturally in the wild (IVA) they would probably be allowed to mature in the wild (VA) and, hopefully, establish a wild pair that would court, lay eggs, and perform all the other processes of their life cycle in the wild. (Note the movement out from the center of the diagram to the outside toward more natural processes.)

Creating Extra Birds for Management Purposes

CAPTIVE BREEDING (IB or C-->IIB or C, etc.)

Captive breeding is of paramount importance in producing birds for management purposes. Admittedly, captive breeding is an expensive, labor intensive effort which can be justified on a large scale only for endangered species. In fact, only two raptors--the Peregrine Falcon and the American Kestrel (Falco sparverius)--are now bred in captivity in sufficient numbers to allow introductions to the wild with a reasonable expectation of subsequent breeding at or near the release sites. The emphasis on Peregrines is more a matter of priority and necessity than a lack of capability to do it with other species --given time and proper funding.

There are currently three major centers of Peregrine Falcon captive breeding in North America. The largest, at Cornell University, is run by Tom J. Cade, James D. Weaver, and Phyllis R. Dague, and is now producing about 100 Peregrines a year (Cade et al. 1977, Cade and Dague 1979). A total of 434 Peregrines have been raised since 1973 at this one facility (Cade and Dague 1978, 1979). A sister establishment, also part of the Cornell Program, which is financed through donations and grants to the Peregrine Fund, is at Fort Collins, Colorado. It is directed by William A. Burnham (1978, 1979). Another 111 Peregrines, mostly the rarest subspecies (Falco peregrinus anatum) have been produced there since 1975. The third facility, at Fort Wainright near Edmonton, Alberta, Canada, is run by Richard W. Fyfe for the Canadian Wildlife Service (Fyfe 1975, 1976). An additional 181 Peregrines have been captive bred at Fort Wainright through the 1979 season (Fyfe 1980 pers. comm.).

Two other large facilities are being developed. One is in Colorado Springs, Colorado, run by Richard A. Graham and the United Peregrine Society (Graham 1979). The other is in Santa Cruz, California, and is directed by Brian J. Walton through the University of California at Santa Cruz (Walton 1979a). Both of these facilities have shown initial successes in recent years and should produce even more birds in the future.

Those who operate these five facilities deserve a great deal of credit for the slowly improving status of the Peregrine in the continental United States, but much of their success is owed to many collaborators, especially many falconers who have donated birds, time, money, and expertise to the overall effort--the so called "back yard" raptor breeders.

The success with captive breeding of Peregrine Falcons, Gyrfalcons (Falco rusticolus), Prairie Falcons (Falco mexicanus), Merlins, and several species of hawks, eagles, kestrels, and owls has certainly provided the impetus to proceed with captive breeding of North America's most endangered raptor--the California Condor (Gymnogyps californianus) (Ricklefs 1978, Kiff 1979). About the only argument left for the purist who would have the California Condor "die on the vine" is the "death with dignity" scenario. However, it is apparent that the "right to life" group--including in this case the U.S. Fish and Wildlife Service, U.S. Forest Service, California Department of Fish and Game, U.S. Bureau of Land Management, American Ornithologists' Union, National Audubon Society, Raptor Research Foundation, and certainly others--have won out. Condors will be trapped for research and captive

breeding efforts beginning in 1980 or 1981 provided the necessary permits and other clearances can be obtained.

In summary, raptors can be bred in captivity; captive bred birds will breed with each other to produce F2 progeny--and surely F3 or F4 by now; and when two Peregrines are bred in captivity, they apparently are not inferior to wild birds. They are, more often than not, healthy, viable, young Peregrines, prime for introduction into the wild by one of several methods.

EGG MANIPULATIONS

Artificial Incubation of Damaged or Thin-shelled Eggs (IA-->IIC-->IIIA)

One symptom of pesticide-laden raptors is the laying of thin-shelled eggs. Perhaps the best example of "clinical ornithology," a concept set forth by David R. Zimmerman (1975) in his book "To Save a Bird in Peril," is if thin-shelled eggs can be removed from nests before they break, many of the embryos can be saved through extraordinary repair work and artificial incubation. This was first tried with Montagu's Harriers (Circus pygargus) in Britain (see discussion following Conder (1964)). Fyfe and Armbruster (1977) also have used this technique on a small scale with Peregrines.

Since 1977, William A. Burnham, in cooperation with Gerald R. Craig of the Colorado Division of Wildlife and James H. Enderson of Colorado College in Colorado Springs, has been been rehabilitating thin-shelled Peregrine eggs brought in from the Rocky Mountain population (Burnham 1979, Burnham et al. 1978). Thus far, 87 fertile wild eggs have been patched, glued, partially covered with parafin, sanded, or just handled carefully before being placed in an incubator for hatching. Fifty-nine of these eggs have resulted in surviving young. A much smaller percentage would have hatched in the wild. In addition, many of these hatchlings have been returned to wild parents. In 1977 the productivity of the Rocky Mountain population was doubled (if not quadrupled) in this way (Cade 1978).

Double-clutching (IA-->IIC-->IIA or IIIA)

Some of the eggs which have been artificially incubated by Burnham (1979) were obtained through the convenient natural backup system now called double-clutching. It has been long and widely known that if eggs are removed early enough (optimum about seven to ten days with large falcons), adult raptors will recycle and lay a second clutch of eggs in about 14 days. Lejeune (1971) suggested that this mechanism be used as a raptor management tool.

Double-clutching has had an added benefit during the pesticide era. Two studies, one of Ospreys (Kennedy 1977a) in this country and another of Peregrines (Monneret 1974, 1978) in Europe, show that second clutches are more productive--presumably thicker shelled and with lower residue levels than first clutches.

Double-clutching can also be used to delay wild pairs 20 to 28 days to put them in synchrony with captive pairs from which foster young might come (Fyfe et al. 1978), or it can be used just to acquire birds for other management purposes (Walton 1979b). Problems include the fact that second clutches often have one less egg (Armbruster 1978, Fyfe et al. 1978); occasionally (10 to 15 percent of the time) the adults (particularly young adults) do not recycle (Armbruster 1978, Fyfe et al. 1978); and, where summer temperatures are high, a four-week delay in hatching may result in heat stress of young birds (Herbert and Herbert 1965, Boyce 1979).

Introduction of Extra Birds to the Wild

Ten years ago, critics were saying that Peregrine Falcons could not be bred in captivity in numbers sufficient to successfully introduce them into the wild. That criticism proved to be unfounded. Five years ago, critics were still saying that introduction to the wild would not work, particularly with any "inferior" Peregrines bred in captivity. Science has again demonstrated the limited vision of the critics. As with captive breeding, breakthroughs with introductions have involved Peregrine Falcons, but each proof of a point with Peregrines adds yet another possible tool to our management repertoire for other raptor species.

The techniques which are now being used to introduce raptors to the wild include clutch augmentation (adding eggs to wild nests), brood augmentation (more specifically fostering and cross-fostering additional young to wild parents), and hacking or controlled release of nestlings. Cade (1978) gives a brief review of introduction techniques as they have been used for endangered birds in general. Temple (1978c) elaborates specifically for birds of prey.

AUGMENTATION

The concept of augmentation is self-explanatory. If extra eggs or young birds are available, one can just place them in nests with other eggs or nestlings, provided they are at about the same stage of incubation or growth. This technique is particularly useful whenever clutch sizes or brood sizes are below normal in wild or captive populations.

Clutch Augmentation (IIA, B, or C-->IIIA)

The ease with which raptor eggs can be switched from one nest to another is perhaps best illustrated by Spitzer's (1978) work with Ospreys, although on-going efforts to save the Rocky Mountain Peregrine Falcon population (Burnham 1979) are also noteworthy. Recent studies of the timing and the extent to which clutch augmentation can be implemented have met with great success. For example, Fyfe et al. (1978) reported an estimated 100 egg swaps among their captive raptors with only two rejections.

In the wild, augmentation has been attempted even in excess of normal sizes of clutches and broods. This may be advisable under some circumstances (i.e. where food is not limiting). The Canadians (Armbruster 1978) have added eggs to wild Prairie Falcon and Peregrine nests to make clutches of six with total success, except for one infertile Prairie Falcon egg. Walton (1977) added extra Prairie Falcon eggs to two nests with complete success. Bennett (1974) reports on the switch of Bald Eagle eggs from Minnesota to Maine.

The usefulness of clutch augmentation has been proved. It is an easy, natural way to ensure that all nests in a population fledge an optimum number of young each year or to introduce captive-produced eggs into nests where wild parents will be available to feed and defend the young that hatch from them.

Brood Augmentation (IIIA, B, or C-->IIIA-->IVA)

Fostering. Data are available on the direct fostering of fourteen species of raptors (Table 1). The objectives of fostering have varied from case to case. Bald Eagles, Golden Eagles, Red-shouldered Hawks, Red-tailed Hawks, Ferruginous Hawks,

Table 1.--Species of raptors that have been fostered.

Species	Reference
Osprey	Fernandez (in Hamerstrom 1977) Postupalsky (in Meyburg 1978) Postupalsky 1978a Spitzer 1978
Bald Eagle	Postupalsky and Holt 1975
White-tailed Sea Eagle (Haliaeetus albicilla)	Fentzloff 1977, 1978 Helander 1976
Red-shouldered Hawk (Buteo lineatus)	Martin and Ruos 1976
Swainson's Hawk	Discussion following Hamerstrom 1974
Red-tailed Hawk (Buteo jamaicensis)	Postupalsky and Holt 1975
Ferruginous Hawk (Buteo regalis)	Olendorff and Stoddart 1974
Imperial Eagle (Aquila heliaca)	Meyburg 1978 Meyburg and Heydt 1973
Golden Eagle (Aquila chrysaetos)	Olendorff and Stoddart 1974
Booted Eagle (Hieraaetus pennatus)	Meyburg 1978 Meyburg and Heydt 1973
American Kestrel	Jones (in Byers 1980)
Prairie Falcon	Cade 1974a Cade and Temple 1977 Fyfe 1976, 1978 Granger 1977 Walton 1977
Peregrine Falcon	Armbruster 1978 Burnham 1979 Cade 1978 Cade and Dague 1977 Fyfe 1976, 1978 Walton 1979b
Eagle Owl	Broo 1977, 1978 Magnusson 1957 Wayre 1975

and American Kestrels have been fostered to other parents to save individual birds or broods after some calamity had befallen their original nest or else one of several in a brood had developed into a runt. Postupalsky (in Meyburg 1978) routinely rescued unusually stunted Osprey nestlings by switching them or their larger nest mates to other nests with success in 24 out of 25 instances. In testing the adequacy of Osprey food resources Spitzer (1978) moved 53 nestling Ospreys (3 to 30 days of age) from Maryland to Connecticut to create normal broods of two and three young. Forty-five of these young fledged successfully. In two cases adult pairs with two young 3 to 4 weeks old were given three new young only 1 week old without rejection problems. Fernandez (in Hamerstrom 1977) placed a chicken egg and later a young Osprey in the nest of a pair of Ospreys that failed to lay eggs. The egg was incubated, and the fostered nestling was reared.

Loss of young Spanish Imperial Eagles (an endangered species) from broods of four in which the last chicks to hatch do not survive has also been alleviated by fostering (Meyburg and Heydt 1973, Meyburg 1978). Fourteen chicks were transferred in one experiment, resulting in the saving of 30 percent of the eaglets hatched by nine pairs. The ultimate measure of success was a 43 percent increase in the number of young fledged by those pairs.

The fostering of Prairie Falcons has been done more as surrogate species management research than to bolster Prairie Falcon populations. The largest of these projects was conducted in Colorado by the Cornell group (Cade 1974a, Cade and Temple 1977). Fourteen young falcons were fostered to wild parents in 1974. One brood was augmented up to a total of seven nestlings. As far as is known, all of the 14 young fledged. Walton (1977) and Fyfe (1978) have fostered smaller numbers of Prairie Falcons in California and Alberta, respectively.

The most extensive fostering programs currently involve the Peregrine Falcon. Fostering Peregrines into the wild began in earnest in 1974 when the Canadian Wildlife Service began double-clutching and augmenting a declining Peregrine population in northern Alberta (Fyfe et al. 1978) and the Cornell group began doing the same in the Rocky Mountains (Burnham 1979). The Alberta population had been studied since 1970. It dropped to a low of three pairs in 1975, but increased to seven in 1977, including the reoccupancy of an eyrie that had not been used since 1966 (Fyfe et al. 1978). Currently the number of breeding pairs is about six or seven, but there are two or three new pairs with young adults which should breed in 1980 (Fyfe 1980 pers. comm.).

The first real breakthrough with any managed Peregrine population came in 1977 when a captive-bred bird from Fort Wainright, that had been fostered to wild parents on the Alberta study area in 1975, returned near its foster home to breed (Fyfe et al. 1978). To illustrate the compounding beneficial effects of these techniques, this bird was double-clutched in 1977. Six of her seven eggs were fertile, three of which she raised in the wild herself. In 1979 four marked birds were breeding in this population (Fyfe 1980 pers. comm.).

In the Rocky Mountain Region, 84 Peregrines have been introduced into the wild by direct fostering since 1974. Fifty-seven of these reached independence (Burnham 1979). Only one returnee has been verified (careful searches for bands were not made), but other one-year-old birds present at eyries in 1979 may prove to be the fostered young.

In summary, experiences with fostering allow considerable optimism. It is a relatively safe technique that has the invaluable advantage of the young being reared and fledged naturally by conspecific parents.

Cross-fostering. Fostering the young of one species to wild parents of another is one of two methods of introducing birds when no conspecific remnant population persists. The other is controlled release or hacking (see below). Ten different cross-fostering combinations are documented in Table 2. Three of these illustrate the current state of the art.

Table 2.--Cross-fostering combinations.

Fostered Species	Parent Species	Reference
Harris' Hawk (Parabuteo unicinctus)	Red-tailed Hawk	Stewart 1979
Common Buzzard	Northern Goshawk (Accipiter gentilis)	Stohn 1974
Ferruginous Hawk	Prairie Falcon	Fyfe et al. 1978
Lesser Spotted Eagle (Aquila pomarina)	Black Kite (Milvus migrans)	Meyburg 1971, 1977, 1978
Lesser Spotted Eagle	Common Buzzard (Buteo buteo)	Meyburg 1971, 1977, 1978
Prairie Falcon	Swainson's Hawk	Fyfe 1976 Fyfe et al. 1978
Prairie Falcon	Red-tailed Hawk	Fyfe 1976 Fyfe et al. 1978
Prairie Falcon	Ferruginous Hawk	Fyfe 1976 Fyfe et al. 1978
Prairie Falcon	Peregrine Falcon	Cade and Dague 1977
Peregrine Falcon	Prairie Falcon	Burnham 1979 Fyfe et al. 1978 Graham 1979 Konkel 1977 Spomer 1979

First, Meyburg (1971, 1977, 1978) has pioneered the technique of cross-fostering Lesser Spotted Eagles to Common Buzzard and Black Kite nests to circumvent the fratricide ("Cainism") that inevitably befalls the weaker eaglet in each nest. By cross-fostering one bird from each nest for several weeks until the Cain and Abel instincts diminish, and then returning the fostered bird to its original nest, Meyburg has nearly doubled the productivity at the manipulated nests (between 15 and 20 instances since 1968) (Meyburg 1978).

Second, Fyfe (1976) and Fyfe et al. (1978) have experimented extensively with cross-fostering Prairie Falcons to three species of buteos and, in one reverse case, Ferruginous Hawks to Prairie Falcons. In 1972 four of five captive bred Prairie Falcons were raised successfully by cliff nesting Ferruginous Hawks. In 1974, 16 young Prairie Falcons were put in three Red-tailed Hawk tree nests and one Swainson's Hawk tree nest in an area 130 km north of the normal range of Prairie Falcons. Two of these cross-fostered young were lost (one to a predator and one to a storm); the remainder fledged and dispersed at about the same time as wild Prairie Falcon young in the general area. Also of interest is the 1977 cross-fostering of 5 young Ferruginous Hawks to Prairie Falcons. All five hawks fell from the falcon eyrie at different ages.

The followup to this work is interesting, but it was still circumstantial in 1977 (Fyfe et al. 1978) when two new Prairie Falcon eyries were found on cliffs along the North Saskatchewan River, well north of the normal Prairie Falcon range and within 30 km of the area where the young were fostered to Red-tailed and Swainson's Hawks in 1974. Also of interest is the two-year occupancy of a Ferruginous hawk cliff nest by Prairie Falcons (the only such record known to the researchers) within 13 km of one cliff nest where Prairie Falcons were cross-fostered to Ferruginous Hawks in 1972.

The third type of cross-fostering experiment is part of the Peregrine Falcon recovery effort. Many historical Peregrine eyries are now occupied by Prairie Falcons (Nelson 1969b, Enderson 1969, Porter and White 1973). This provides an excellent opportunity for congeneric cross-fostering where Peregrines no longer exist.

The first serious cross-fostering of Peregrines to Prairie Falcons began in 1977 at the Snake River Birds of Prey Natural Area (Konkel 1977, Burnham 1977, Cade and Dague 1978). Three anatum Peregrines were cross-fostered that year with complete success. In 1978 five Peregrines were cross-fostered into two separate eyries. Two fledged successfuly from one eyrie, but a combination of a bed bug infestation and owl predation caused complete failure at the other. In 1979 there was no success with cross-fostering at the Snake River Birds of Prey Natural Area (Burnham 1979). Three Peregrines were put in one Prairie Falcon eyrie: two were lost in a nighttime wind storm; the other was struck by a neighboring Prairie Falcon.

Other attempts to cross-foster Peregrines to Prairie Falcons were made by the Cornell group in 1979 in South Dakota (3 birds) (Spomer 1979), Nebraska (3 birds), and Colorado (6 birds) (Burnham 1979). An additional attempt by Graham (1979) in Colorado involved two birds. Of these 14 birds, only six reached independence due to avian predation (Golden Eagles and, perhaps, Great Horned Owls (Bubo virginianus)) and diseases (pneumonia and a sporozoan disease similar to malaria).

Thus, the optimism which followed the successful cross-fostering in Idaho in 1977 has given way to a more cautious approach of using this technique only where other methods are unavailable. Even controlled release (i.e. hacking) in the

absence of protective parents has been more successful than cross-fostering (see below). As a result, cross-fostering of Peregrines to Prairie Falcons apparently will be deemphasized during the next few years (Burnham 1979), not so much because it will not work, but, again, as a matter of priority. It is a better investment of young Peregrines to augment existing populations rather than step out into areas of historical occupancy. It is a simple numbers game. An estimated 60 young Peregrines released over a two- or three-year period would be needed to establish a marginally viable isolated population of three pairs (Burnham 1979). When more young Peregrines are available, perhaps cross-fostering in unoccupied historical habitat will be more cost effective--in dollars and in falcons.

HACKING

The technique of removing young raptors from their nests and fledging them from some artificial structure or nest was developed by falconers to provide their birds with a degree of natural experience before being taken into captivity for falconry training (Michell 1900, Blaine 1936, Mavrogordato 1966). By supplying food to the birds for a longer period of time--until they are capable of killing for themselves--they can gradually be returned completely to the wild in a predetermined place.

The hacking of raptors as a species management technique is limited almost exclusively to the 1970s. A few exceptions follow. Wayre (1970, 1975) released young Barn Owls (Tyto alba) and Little Owls (Athene noctua) by feeding them each night on top of their parents' aviaries during the late 1960s. Swedish ornithologists have been breeding Eagle Owls in captivity and releasing the young by several hacking techniques since the mid-1950s (Magnusson 1957; Wayre 1970, 1975; Broo 1977, 1978). An unsuccessful attempt to hack White-tailed Sea Eagles on the Isle of Rhum occurred in 1968 (Everett 1978), although Love and Ball (1979) are having better luck with the same species in the same area. Twenty-four eagles have been released successfully since 1975.

Bald Eagles were hacked successfully in 1976 and 1977 (Milburn 1977; Cade and Dague 1976, 1977) at the Montezuma National Wildlife Refuge in New York. One of the two birds released the first year returned to the refuge in August of 1977, thirteen months after being released and ten months after dispersing. Five more eaglets were hacked successfully in 1977.

During the spring and fall of 1979, an attempt to hack fourteen Harris' Hawks of varying ages and captive histories was made along the Lower Colorado River where this species had been extirpated (Stewart 1979, Gallagher 1980). There has been an apparent increase in the number of Harris' Hawk sightings in the general area (several in September 1979) (Conrad 1979b, Gallagher 1980). This work continued during the spring of 1980 with the release of a pair that had previously bred in captivity (Walton 1980 pers. comm.). Within one month the pair built a nest and laid eggs. Two aspects of this release are particularly noteworthy. First, the birds were taken from the wild as eyasses. They had no previous experience in the wild. Second, they nested within 100 yards of the point of release. Mature birds released into the wild generally dissappear and are never seen again.

All other hacking projects mentioned in the literature reviewed for this paper involve the Peregrine Falcon recovery effort. This includes preliminary work with Prairie Falcons as a surrogate species. Three Prairie Falcons were hacked in New Mexico in 1974 (Cade 1974a), and six more were hacked at the Colorado State Prison at Canon City in 1975. All nine birds fledged successfully.

The largest hacking program has been conducted with Peregrine Falcons by the Cornell group in the eastern United States where the Peregrine was extirpated during the early 1960s. The pioneering attempt was made by Heinz Meng from atop the 10-story high Faculty Tower on the New York State University College campus in New Paltz (Meng 1974, Meng and Kaufman 1975, Kaufman and Meng 1975, Cade 1974a). Two birds bred in captivity at Cornell were placed at the hacking site in New Paltz one week before being able to fly. Both fledged successfully. However, one was killed a short time later, apparently by someone who did not care to have pigeon-killing birds in an urban environment. The second bird was never seen after it dispersed.

In 1975 sixteen Peregrines were hacked at five sites in Maryland, New York, Massachussets, and New Jersey (see Cade 1978 or Sherrod and Cade 1978 for details about techniques). Twelve of these birds fledged, and five (42 percent) returned to hack sites in 1976 (Cade and Dague 1976). The first pair formation occurred in 1978 at Sedge Island, New Jersey (Cade and Dague 1978), where a male released in 1975 had been returning every year since 1976. Ten or 11 adult or subadult Peregrines returned to eight different hack sites in 1978.

By 1979 success began interfering with further introductions at some hack sites (Cade and Dague 1979). A total of 211 Peregrines were hacked into the wild in the eastern States between 1974 and 1979. Of these, 150 (or 71 percent) reached independence. Returnees in 1979 included: 1) a single female that laid infertile eggs (the first in 20 years in the East) on a building in Baltimore and subsequently raised two foster young by herself; 2) pairs at all three hacking towers in New Jersey (one of which produced fertile eggs that were later destroyed by crows); and 3) eight individuals at other sites in the east for a total of 15 (i.e. 10 percent of those successfully hacked and 14 percent of those that dispersed from the hacking stations between 1974 and 1978). Successful breeding should occur in 1980.

Hacking of Peregrines began in the Rocky Mountains in 1978 (Burnham 1978). At one site in New Mexico four birds were hacked into a territory of a wild pair that had failed. When the young birds flew, they were attacked by the resident adults and therefore were removed from the site. The other 1978 attempt was in Rocky Mountain National Park. Five birds were hacked; all reached independence. One returned to the site in 1979 (Burnham 1979) while five more young were being released there. In all, 24 Peregrines have been hacked in the Rocky Mountains (New Mexico, Colorado, and Utah). Nineteen of these (79 percent) have reached independence.

It is difficult to portray the excitement of these successes in words. Again, the techniques are working, and the birds apparently are not inferior to non-introduced Peregrines. One male returnee called the "Red Baron" is exemplary. He was observed chasing prey 93 times in 1979, and he was successful 90 of them (Cade and Dague 1979). At one stretch he made 60 consecutive kills. Tom Cade put it nicely in the 1979 Peregrine Fund Newsletter, and he more than any other person should be the judge:

> When I watch this magnificent tiercel hunt, I am reminded of another time and place, 5,000 miles away on the Yukon River where I have seen the wild relatives of this very falcon make similar hunts after winnowing snipe high over the boreal forest. What has been said of the California condor may have meaning in some poetical sense; but for these falcons, I tell you truly, I cannot see a difference with my eyes, nor do I feel a difference in my heart, which pounds against my chest with the same vicarious excitement when the Red Baron stoops over the New Jersey salt marshes, as it did in 1951 when I first saw this high flying style of hunting performed by the wilderness inhabiting peregrines of Alaska.

HABITAT PROTECTION

Habitat protection is accomplished primarily by making land managers and the general public more aware of raptor habitats and by controlling the use and development of raptor habitats wherever necessary and possible. This can be done in many ways, including: 1) enactment of legislation and enforcement of related regulations (many of which are for other purposes, e.g., wilderness legislation, air and water quality standards, etc.); 2) land-use planning, 3) environmental assessment; 4) creation and designation of special areas; and 5) public education.

The ultimate in habitat protection would be "to set aside as nature reserves at least one big area of each...self-supporting or closed ecosystem where birds of prey occur in large numbers and species and to intensify the conservation of these birds because they are still plentiful" (Voous 1977). We may see this happen in the decade of the Eighties or Nineties, but it is not now politically feasible. We must, therefore rely on a combination of the other available techniques.

Legislation

The most important legislation concerning habitat protection and management on federally administered lands was reviewed briefly by Olendorff and Zeedyk (1978). The Critical Habitat provisions of the Endangered Species Act of 1973 (as amended) are particularly noteworthy (Porter and Marshall 1977, Wilbur 1978). The current regulations concerning Critical Habitat are published in Parts 17, 402, and 424 of Chapter IV of Title 50 of the U.S. Code of Federal Regulations (see Federal Register 45(40): 13010-13026, February 27, 1980, for the most recent release).

Designation of Critical Habitats is a controversial issue in that it discloses sensitive eyrie information, an act in itself which could jeopardize the continued existence of particular pairs of endangered birds. Thus, in California where five Critical Habitats have been officially designated for the Peregrine Falcon, the active, published eyrie sites are watched throughout the nesting season on a 24-hour, 7-day-per-week basis (Harlow 1977, 1978; Boyce 1979). The nine California Condor Critical Habitat Zones are not watched as closely, but all land management actions which may adversely impact these areas are reviewed through the Endangered Species Act consultation processes.

The only other federally determined Critical Habitat for an endangered raptor is for the Everglade Kite (Rostrhamus sociabilis) in Florida. However, the State of Alaska has implemented its own Critical Habitat legislation on a smaller scale, principally to protect a stretch of the Chilkat River which in some winters supports 3,000-3,500 Bald Eagles (Snow 1973).

Less specific but still very germane to raptor conservation are the multiple-use, sustained-yield mandates under which the major land managing agencies operate (e.g., U.S. Bureau of Land Management and U.S. Forest Service) (Olendorff and Zeedyk 1978). These laws establish broad guidelines for inventory, research, land-use planning, and environmental assessment, all of which have aided raptor conservation. An analysis of Federal Government involvement (United States and Canada) in the subject matter and/or authorship of the papers cited herein indicates that 50-60 percent of the raptor programs in North America are federally supported, primarily as a result of new laws passed in the 1970s. Some of the more significant of the land-use laws include the Sikes Act as amended in 1974, Resources Planning Act of 1974, National Forest Management Act of 1976, and the Federal Land Policy and Management Act of 1976.

Land-use Planning

The most intensive land-use planning to benefit raptors must certainly be for the 100 nesting pairs of Bald Eagles on or near the Chippewa National Forest in north-central Minnesota (Mathisen et al. 1977, Mathisen 1978). Each territory is described in a management plan based on a field examination of the nest location, nest tree characteristics, special threats to the territory, and surrounding habitat. Photographs and maps add to the visual record of the territory. A narrative is then prepared consisting of six elements: description of the territory, nest site characteristics, pair behavior, nesting history, additional research data, and management constraints.

The management constraints apply to several concentric buffer zones around the nests including the following: 330-foot zone (100 meters)--no activity; 660-foot zone (200 meters)--no activity from February 15 to October 1, and very little activity the rest of the year; and 1,320-foot zone (400 meters)--no activity from February 15 to October 1, but no restrictions on activities the rest of the year. The 1,320-foot zone can be extended an additional 1,320 feet if justified in the management plan.

Buffer zones to protect raptors have been prescribed in U.S. Forest Service land-use plans since 1963 (Mathisen 1968). The most common approach in the western United States has been to designate circular primary and secondary management zones, activities being more restricted in the primary zones (U.S. Forest Service 1977, U.S. Fish and Wildlife Service 1977). Now, however, more information is allowing the delineation of irregular zones based on topography, foraging patterns, the limits of territoriality or defense behavior, and even the distribution of trees which themselves can buffer the birds from disturbance. The work by Stalmaster (1976) and Stalmaster and Newman (1978) on Bald Eagle habitat utilization and recommended buffer zones is particularly useful. Other Bald Eagle buffer zones are recommended by Coffey (1977) and Steenhof (1977), and Helander (1977) gives recommendations for the closely related White-tailed Sea Eagle.

Buffer zone recommendations are also available for other species: Osprey--Roberts (1969, 1970), Kahl (1972b), Kahl and Garber (1971), Radtke (1973), Garber et al. (1974), Gale and Forkis (1974), Zarn (1974a); California Condor--Wilbur (1978a), Sibley (1969); Peregrine Falcon--Haugh and Halperin (1976), Monk (1979), Ellis (1978), and Enderson and Kirven (1979); Accipiters--Tankersley (1976), Luckett (1977), and Jones (1979); and Spotted Owl (Strix occidentalis)--Zarn (1974b) and Gould (1974).

A similar nest territory plan program is currently in effect for all Bald Eagle territories in California. Seventy plans are in various stages of development and approval, an effort which is coordinated by the California Bald Eagle Working Team. The prototype Peregrine Falcon nest territory plan is currently being developed by the California Peregrine Falcon Working Team.

Land-use planning on a broader scale can also protect raptor habitats. The U.S. Bureau of Land Management planning system provides a useful example (Olendorff and Kochert 1977). The Bureau has divided its land into about 650 geographic units on which land-use plans are made. Raptor habitats are routinely identified during the planning process in most units, particularly in the preparation of a document called the Management Situation Analysis (formerly the Unit Resource Analysis).

This analysis also contains data on general wildlife habitat conditions and land management potentials, as well as on all other resources. These data are correlated in the final document using tables, map overlays, and narratives explaining each resource. Habitat inventories for birds of prey yield input into these planning analyses.

The results of U.S. Bureau of Land Management surveys of raptor habitats often include maps of important raptor areas, base-line data for establishing raptor population trend studies, and detailed narratives concerning the biological as well as the aesthetic values of raptors. Such information is later used to develop a second document called the Resource Management Plan. This long-range plan provides a framework of multipe-use coordination among the various resource program activities. It establishes objectives and constraints for each resource, including wildlife. For example, in Idaho much of the management of the Snake River Birds of Prey Natural Area is supported by Resource Management Plan recommendations.

Another planning mechanism provides a firm basis for short-term, on-the-ground enhancement of wildlife habitat. To ensure proper planning of enhancement projects, Habitat Management Plans are written by the Bureau of Land Management wildlife staff. The Bureau currently has nearly 200 of these site-specific plans in various stages of preparation and implementation in the contiguous Western States. Several of the 200 have direct raptor habitat management implications.

Most other federal and state agencies also have planning systems that benefit raptors, at least to the extent that other wildlife resources are benefitted. This aspect of wildlife conservation is too frequently overlooked by non-agency wildlife advocates, when, in fact, it may be the only way to effect meaningful protection.

Environmental Assessment

Knowledge of many raptor populations increased exponentially during the 1970s due, in large part, to the requirements of the National Environmental Policy Act of 1969 and the Endangered Species Act of 1973. Virtually every Federal action requires at least an environmental assessment. Hundreds of these documents are prepared each year, and many require raptor inventory data. Some larger or more controversial actions require a full environmental impact statement (Olendorff and Kochert 1977; Fyfe and Armbruster 1977). The value of raptor data gathered for these statements is grossly underrated because it usually is not published. Public input is an important component of this process that should be used to the fullest extent possible.

Designation of Special Areas

The need for designation of special areas where raptors can breed and winter relatively free of disturbance was reflected in resolutions passed at the 1975 World Conference on Birds of Prey in Vienna, Austria (Chancellor 1977). The conferees urged "national conservation bodies and governments to set aside sufficient representative nature reserves where birds of prey live in large variety and abundance and to conserve these birds while they are still plentiful." We are making progress in the United States toward such a goal by setting aside National Wildlife Refuges, natural areas, raptor management areas, and sanctuaries. In addition, wilderness areas, wild and scenic rivers, National Parks, and National Monuments provide de facto protection for many raptors (Murphy 1978).

NATIONAL WILDLIFE REFUGES

Several National Wildlife Refuges were newly created in the 1970s specifically for endangered raptors, including four for the Bald Eagle in Maine, California, Virginia (Deane 1966, 1967, 1968), and South Dakota (Graham 1976, Anonymous 1974, Nesbitt 1975); one for the California Condor; and one for the Peregine Falcon in New Hampshire (a bit late!). Certain other refuges have active raptor management programs, including the Glen L. Martin near Chesapeake Bay with its Osprey nesting platforms (Rhodes 1972, 1977); Brigantine, one of the Peregrine Falcon hacking sites (Cade and Dague 1976); and Montezuma, a hack site for Bald Eagles (Milburn 1977, Cade and Dague 1976, 1977).

NATURAL AREAS

Two areas called natural areas were established in the 1970s. The Skagit River Bald Eagle Natural Area was dedicated by Washington Governor Daniel Evans on February 6, 1976 (Margolis 1974, Beebe 1976, Davis 1976). The effort and cost expended by the Nature Conservancy and other cooperators to get this and similar areas set up provides detailed lessons in the use of techniques such as land acquisitions, conservation easements, land exchanges, and land withdrawals to promote raptor habitat protection. The result in this case is a continuous seven-mile corridor of vital eagle habitat (Servheen 1975) along the Skagit River which is now controlled by the Nature Conservancy and the Washington Department of Game.

The largest and most publicized natural area designed for raptor habitat protection is the Snake River Birds of Prey Natural Area administered by the U.S. Bureau of Land Management (Chaney 1979; Meiners 1971; U.S. Bureau of Land Management 1975, 1976, 1977; Zwinger 1977; Haley 1978). Through the early initiative of U.S. Bureau of Land Management employees, such as Bill Meiners and Edward Booker, and raptor expert Morlan Nelson, this 26,300-acre natural area was created in 1971 (Dunstan 1979b). Since then, under the principal leadership of Michael Kochert and with excellent support from the Bureau of Land Management Boise District Manager Dean Bibles, an extensive research program has justified the creation of a larger 515,000-acre National Conservation Area (U.S. Bureau of Land Mangement 1979), including the foraging habitat of the birds. The proposal is now in the hands of the Secretary of the Interior and is awaiting introduction to Congress. In this one case Voous' (1977) objective of setting aside self-supporting ecosystems where birds of prey are still abundant is being met.

MANAGEMENT AREAS

Designation of important raptor habitat as management areas seems to carry less legal backing than the other special areas discussed above, but the management area concept is still a valuable tool. Three such management areas were designated--all by the U.S. Forest Service--during the late 1960s and early 1970s.

reservoir was flooded without clearing the timber. Thus, in a few years the ponderosa pine snags became prime habitat for about 35 pairs of nesting Ospreys. A few of the restrictions in effect at this reservoir include no cutting in a 200-foot-wide strip immediately adjacent to the reservoir; restricted cutting for the next 1,120 feet away from the reservoir where at least two dominant trees per acre must be left; a 132-foot-wide "no-cut" buffer zone around each nest; a "restricted activity" zone 660 feet on all sides of the nest; and no hunting from April 1 to September 30 each year. Management programs include signing of nest trees and erection of artificial nest sites as needed to replace downed snags.

SANCTUARIES

Today the term "sanctuary" is more often applied to special areas privately owned by individuals or organizations. Two exceptions are the California Condor sanctuaries on the Los Padres National Forest just north of Los Angeles (Wilbur 1978a, Mallette and Schlorff 1978) which have existed for several decades. The 1,200-acre Sisquoc Condor Sanctuary was established in 1937, while the 53,000-acre Sespe Condor Sanctuary was designated in 1947. Both are essentially closed to public use.

The most famous raptor sanctuary in North America is Hawk Mountain Sanctuary established in the mid-1930s near Drehersville, Pennsylvania, where thousands of people enjoy hawk watching each fall during the eastern migration (Collins 1935, Edge 1936, Broun 1949, Brett and Nagy 1973, Harwood 1973, Heintzelman 1975, Nagy 1978a). Another example is the Children's Bald Eagle Nesting Area in Minnesota, bought by Hunt and Wesson after children turned in about a million and a half bean can labels. The four sites purchased, totaling about 114 acres, were later turned over to the Chippewa National Forest for management (Mathisen 1973).

In a similar case, the Illinois Audubon Society's "Dimes for Eagles" program in the public schools helped the Nature Conservancy purchase 580 acres of Bald Eagle winter habitat along the Mississippi River which housed 454 Bald Eagles during the National Wildlife Federation's 1979 mid-winter Bald Eagle survey (Dunstan 1979a). Part of this area is known as the Children's Eagle Refuge. An excellent symposium on preservation and acquisition of Bald Eagle habitat was conducted in 1975 (Ingram 1975).

The National Audubon Society has three sanctuaries which emphasize raptor habitat protection (Graham 1978). The Okeechobee and Observation Shoal Sanctuaries (28,250 acres combined) contain the best breeding habitat for the endangered Everglade Kite. Some of the finest shortgrass prairie raptor habitats occur on the 14,800-acre Eagle Rock Audubon Sanctuary in northeastern Colorado which is private land leased from Mark T. Cox III of Cheyenne, Wyoming.

HABITAT MANAGEMENT

Habitat management generally involves some physical change or development of an area to make it more suited to the needs of one or more species (Call 1979). Protection of raptor populations in naturally diverse and relatively undisturbed habitats (discussed in the previous section) does not as a rule require habitat management. However, habitat management is frequently necessary and justifiable 1) in developing larger raptor populations where some crucial habitat requirement is lacking (e.g., where prey resources are adequate, but no nest sites exist); 2) in mitigating the impacts of agricultural, industrial, urban, recreational, and other

land uses on raptor habitats; and 3) in reclaiming habitats following extensive degradation caused by mining, off-road vehicle abuse, livestock grazing (especially in riparian areas), or any other surface disturbing activity.

Nearly all past and present raptor habitat management projects can be categorized as follows: 1) manipulation of prey populations; 2) manipulation of vegetation; 3) artificial feeding; 4) management of perches; and 5) provision of artificial nests and nesting structures. The decade of the 1970s was a period of considerable uncoordinated "small-time" experimentation with raptor habitat management, but very little research with sound experimental design was conducted. Only the development of artificial nestboxes for kestrels and small owls and of artificial platforms for Ospreys now produce predictable desired results.

Management of Prey Resources

Management of prey resources includes direct manipulation of prey populations; manipulations of plant composition, density, and structure (and thereby prey numbers) to benefit raptors; artificial feeding of raptors; and management of perches to facilitate raptor feeding.

MANIPULATION OF PREY POPULATIONS

The state of the art of managing prey populations to benefit raptors is not well advanced, although we have learned a great deal inadvertently or as a by-product of other management. For example, on the Shasta-Trinity National Forest, Bogener (1979) found that Ospreys which nest within 1.5 miles of fish stocking sites produce more young that those that nest further away. Also, there is considerable literature on the opportunistic nature of birds of prey in taking advantage of abundant prey resources--both short-term and long-term--no matter how the excesses may have developed. The converse is also true; a long-term decrease in prey resources usually causes a long-term decrease in raptor populations. Hodson (1976), for example, attributes the decrease of nesting Merlins in parts of Canada to a decrease in prey availability caused by the conversion of native grassland (which supported adequate passerine populations) to agriculture (which supports far fewer passerines).

Most recommendations concerning direct management of raptor prey populations are for Bald Eagles (Radtke 1973, Beebe 1976, Steenhof 1977, Conrad 1979a). These include 1) maintenance and restoration of natural runs of anadromous fish; 2) stocking of fish where they would be vulnerable to Bald Eagle predation (sloughs, backwaters, small impoundments); 3) allowing commercial and recreational fishing only to the extent that it does not interfere with effective predation by Bald Eagles; 4) manipulating water levels in reservoirs to facilitate eagle predation; 5) discouraging stream channelization; and 6) promoting habitat improvement projects for upland game and waterfowl.

Some of these recommendations follow from field observations. Spencer (1976) reports an increase in wintering Bald Eagles on the Monte Vista National Wildlife Refuge in Colorado to over 200 birds following waterfowl habitat improvements. McClelland (1973) documented tremendous increases in Bald Eagle use of Glacier National Park following the establishment of a Kokanee salmon run in the park. Spencer (1976) cites similar examples in Colorado, Oregon, California, Idaho, and New Mexico.

Schnell (1979) recommends the installation of low cross dams along streams in Common Black Hawk (Buteogallus anthracinus) habitat to concentrate fish and frogs near nest sites.

MANIPULATION OF VEGETATION

In general, it is not financially feasible to manipulate vegetation on a large scale solely to increase raptor prey populations. It is more realistic to gain concessions for raptors as part of other ongoing management. For example, range management practices that maintain ranges in good condition will provide an adequate prey base for many raptorial species (Craighead and Craighead 1956). Olendorff and Stoddart (1974) indicate that the largest, most closely controlled private ranches in northeastern Colorado are the best habitat for most resident raptors. While this relates to minimizing human disturbance at nests, it also indicates an adequate prey base.

The primary effect of livestock grazing on raptors is an indirect influence produced by changes in vegetation composition, density, and structure. These changes in cover and shelter for wildlife produce concurrent changes in small mammal, bird, reptile, and amphibian populations. Lower vegetation with lesser density tends to make small rodents and lagomorphs more vulnerable to predation. Thus, moderate to heavy livestock grazing of sagebrush (outside of riparian areas!) for several consecutive years in winter may cause the death of many of the plants, open up the area, and thereby facilitate raptor predation during the ensuing summers.

By knowing the specific prey requirements of the various raptors, land managers can benefit particular species of raptors through different kinds of vegetation conversion projects. Where possible, brushland habitats and grasslands should be retained in a random arrangement--a mosaic--within the planned vegetation treatment area. Another alternative is the scatter pattern of exclosures suggested by Hamerstrom et al. (1957) for Prairie Chickens (Tympanuchus cupido). The concept of "edges" and their beneficial effects on animal species diversity (see Thomas et al. 1979 for a recent review) should also be incorporated into any land conversion project designed to increase prey populations for raptors. Large monocultures of crested wheatgrass, for example, should be broken into smaller units interspersed with at least 20 percent native plant communities (Howard 1975, Howard and Wolfe 1976).

Removal of juniper from native sagebrush/grassland habitats followed by effective reseeding has been shown to increase small rodent (primarily mouse) populations for at least two years following treatment (Baker and Frischnecht 1973). In addition, Westoby and Wagner (1973) found that jackrabbit numbers are generally higher in desert shrub vegetation near edges with grassland. Howard and Wolfe (1976) infer that these findings could be applied in future land conversion projects to benefit Ferruginous Hawks.

Everett (1978) suggests that habitat management for the Marsh Harrier (Circus aeruginosus) could be extremely beneficial. This would involve purposeful reintroduction of reedbeds on a large scale.

ARTIFICIAL FEEDING

Artificial feeding of raptors at winter concentration areas is done for several reasons: 1) to ensure that food sources are available at all times, especially during bad weather, 2) to offer a pesticide-free diet to contaminated raptor populations exhibiting poor reproductive success; 3) to reduce the probability that vultures will feed on poisoned baits; and 4) to augment food supply during the breeding season. Such programs are recommended only for endangered raptors and only when food resources are inadequate or contaminated (Archibald 1978).

The major artificial feeding programs are for White-tailed Sea Eagles (Helander 1978), various Old World vultures (Biljeveld 1974, Zimmerman 1975, Archibald 1978, Iribarren 1977, Schenk 1977), and the California Condor (Wilbur et al. 1974; Wilbur 1978a, 1978b). Artificial feeding of Ospreys was conducted from 1966-1972 in southern New Jersey by Herbert H. Mills (Graham 1973, Mills 1977). Dead menhaden (up to three per day) were placed near frequently used perches and were usually taken by the birds as soon as Mills left the perch area. Beebe (1976), Steenhof (1977), and Detrich (1978a) recommend artificial feeding for Bald Eagles, but to date no such programs have been implemented for this species. Bergman (1977) reports artificial feeding of Golden Eagles in Finland.

Sweden's White-tailed Sea Eagle artificial feeding program is the largest of its type (Helander 1978). Over 100 tons of food are put out each year at nearly 100 stations. The objective is to supply the eagles with pesticide-free food, including primarily slaughterhouse offal and whole animals obtained on an opportunistic basis (e.g., roadkills and dead domestic stock). While the number of immature White-tailed Sea Eagles at feeding stations has increased since 1971 (possibly through a learned behavior), an increase in productivity on the nesting grounds has not been noted.

The California Condor artificial feeding program has shown similar results; condors use the stations, but no increase in breeding has occurred since the program's inception in 1971. However, artificial feeding of condors may be serving another purpose. In recent years, the remaining birds have been congregating further and further away from nesting areas. The feeding stations are near the breeding areas and may be functioning to preserve traditional ties to nesting areas on the Sisquoc and Sespe Condor Sanctuaries. Nonetheless, this program is not without critics (e.g., McMillan 1965).

The problems of European and Middle Eastern Griffon Vultures (Gyps fulvus) involve an overall shortage of food and the widespread use of pesticides. A breeding colony of three pairs established itself about 1 km from a Griffon Vulture feeding station in Isreal (Mendelssohn in Archibald 1978). Other vulture restaurants include two in Sardinia and six in Spain.

The feasibility of artificial feeding programs for non-carrion-eating raptors has been shown in many ways. Raptors are easily trapped using live baits for research and falconry purposes. A large portion of the Spanish Peregrine Falcon population exists on artificial food provided by the hundreds of dovecotes scattered across the country. Artificial feeding of young Peregrines is an integral part of the Peregrine introduction efforts (e.g., Sherrod and Cade 1978). Felton (in Thelander 1978) provided live pheasants and pigeons to a female Peregrine Falcon that was rearing a single fostered young after the death of the male. The young bird eventually fledged.

MANAGEMENT OF PERCHES

The use of artificial structures by perching raptors is as commonplace as the utility pole. Telephone poles, electric transmission towers, and electric distribution poles have altered the hunting strategies of dozens of species of raptors by opening up millions of acres of habitat to hunting from a stationary perch. The extent to which a new line is used was shown by Stahlecker (1978) in a "before-and after" study along an electric transmission line in east-central Colorado. Use of pre-existing perches decreased and raptor densities increased significantly after the new line was built. Marion and Ryder (1975) found that Rough-legged Hawks (Buteo lagopus) and Prairie Falcons preferred high man-made perches, particularly electric distribution poles.

This preference for perching on power poles has also had negative effects on raptors, particularly the Golden Eagle, through electrocution, a problem which has been known for at least 40 years (Marshall 1940, Dickinson 1957). In the same area of northeastern Colorado that was studied by Marion and Ryder (1975), Olendorff (1972) reported that 17 Golden Eagles were found dead under 3 1/2 miles of powerlines. Other similar reports followed, both in North America (Smith and Murphy 1972, Laycock 1973, Boeker and Nickerson 1975) and abroad (Markus 1972, Garzon 1977).

This increased interest in raptor electrocutions stimulated a cooperative effort coordinated by Richard S. Thorsell of the Edison Electric Institute to address the problem. As a result, numerous federal agencies, conservation organizations, and private electric companies supported the development of "Suggested Practices for Raptor Protection on Powerlines" (Miller et al. 1975). This booklet includes numerous detailed specifications for eagle-safe powerlines, many of which were researched and developed by Morlan Nelson (Nelson and Nelson 1976, 1977; Nelson 1978). A recent symposium on raptors and energy development will update the status of this issue (Howard and Gore 1980).

The use of perches erected specifically for raptors has not been particularly successful. Steenhof (1977) reports that the U.S. Army Corps of Engineers erected four perch poles for Bald Eagles below Ft. Randall Dam, South Dakota. Bald Eagles were seen on them only two times in two years. Similar poor results have occurred in Oregon (Opp in Steenhof 1977). Biologists from the U.S. Bureau of Reclamation noted that the small nesting population of Bald Eagles in central Arizona was without hunting perches along extensive stretches of river. Twelve 40- to 60-foot poles were erected along the river in December 1976 (Stumpf 1977), but no followup is available.

Use of raptor perches to control rodent populations has received recent attention in California. Hall et al. (1978, 1979) proved that raptors would use their artificial perches, but could not relate perch use to decreases in rodent populations.

The U.S. Bureau of Land Management has funded two experimental perch-pole projects. Two poles erected near Saguache, Colorado, in large prairie dog towns have been used by Ferruginous Hawks, Red-tailed Hawks, Marsh Hawks (Circus cyaneus), and Golden Eagles (Snow 1974). Warburton (1972) erected eight artificial nesting/perching structures for large raptors in Puddle Valley, Utah, in 1972. The structures were frequently used as perches, and at least one unsuccessful nesting attempt by Golden Eagles occurred during the first two years, but long-term followup is unavailable.

Provision of Artificial Nests and Nesting Structures

Documentation of raptor nesting on man-made structures which were not intended for such purposes is beyond the scope of this paper. A general familiarity with this topic, which indicates the potential for raptors to use artificial structures erected specifically for them, can be gained from Herbert and Herbert (1965) and Hickey (1969) for Peregrine Falcons; Henny (1977b) for Ospreys; Gilmer and Wiehe (1977) for Ferruginous Hawks; and Olendorff and Stoddart (1974), Newton (1976), and Call (1979) for a variety of species.

Interest in artificial nests and nest structures specifically designed for raptors as a raptor habitat management technique was very high at the end of the 1970s (Table 3). Of 95 references to successes with artificial nests and nesting

Table 3.--Species of raptors that have used artificial nesting structures (i.e. structures designed and erected specifically for raptors) and artificial nests (nests built by man to look like natural nests).

Species	Reference	Nest Type
Osprey	Ames and Mersereau 1964	Platforms
	Bergman 1977	Artificial Nests
	Bogener 1979	Platforms
	Detrich 1978b	Platforms
	Garber et al. 1974	Platforms
	Henny et al. 1978a	Platforms
	Jacobs 1977	Platforms
	Kahl 1972a, 1972b	Platforms
	Kennedy 1977b	Platforms
	Lee 1980	Platforms
	Nelson 1978	Platforms
	Persson (in Saurola 1978)	Artificial Nests
	Postupalsky 1978a	Platforms
	Postupalsky and Stackpole 1974	Platforms
	Reese 1965, 1970, 1977a, 1977b	Platforms
	Rhodes 1972, 1977	Platforms
	Saurola 1976, 1978	Artificial Nests
	Schey (in Saurola 1978)	Artificial Nests
	Sietke (in Saurola 1978)	Platforms
	Valentine 1967	Platforms
Honey-Buzzard (Pernis apivorus)	Rouhiainen et al. (in Saurola 1978)	Artificial Nests
Everglade Kite	Graham 1978	Wire Baskets
	Kern 1978	Wire Baskets
	Sykes and Chandler 1974	Wire Baskets
Bald Eagle	Dunstan and Borth 1970	Artificial Nests
	Grubb (in Call 1979)	Platforms
	Lamb and Barager 1978	Platforms
	Nelson 1978	Platforms
	Postupalsky 1978a, 1978b	Platforms
White-tailed Sea Eagle	Helander 1975, 1977	Artificial Nests
	Kulves (in Saurola 1978)	Platforms
European Sparrow-hawk	Saurola 1978	Artificial Nests
Northern Goshawk	Bijleveld 1974	Artificial Nests
	Persson (in Saurola 1978)	Artificial Nests
	Rouhiainen et al. (in Saurola 1978)	Artificial Nests
	Saurola 1978	Artificial Nests

Table 3.--Continued.

Species	Reference	Nest Type
Swainson's Hawk	Fitzner 1980 pers. comm. (see text)	Platforms
	Fitzner 1980 pers. comm. (see text)	Artificial Nests
Red-tailed Hawk	Dunstan and Harrell 1973	Artificial Nests
	Henny et al. 1978a	Platforms
	Lee 1980	Platforms
	Nelson 1978	Platforms
	Nero et al. 1974	Artificial Nests
	Scott 1970, 1978	Platforms
Common Buzzard	Berggren 1975	Artificial Nests
	Persson (in Saurola 1978)	Artificial Nests
	Rouhiainen et al. (in Saurola 1978)	Artificial Nests
	Saurola 1978	Artificial Nests
Rough-legged Buzzard	Berggren 1975	Artificial Nests
	Saurola 1978	Artificial Nests
Ferruginous Hawk	Anderson (in Call 1979)	Platforms
	Call 1979	Wire Baskets
	Fyfe and Armbruster 1977	Wire Baskets
	Howard and Hilliard 1980	Platforms
Golden Eagle	Berggren 1975	Artificial Nests
	Call 1979	Wire Baskets
	Craig and Anderson (in Call 1979)	Platforms
	Kellomaki (in Bergman 1977)	Artificial Nests
	Nelson 1978	Platforms
	Nelson and Nelson 1977	Platforms
	Saurola 1978	Artificial Nests
	Warburton 1972	Platforms
American Kestrel	Bloom 1977, 1978	Nestboxes
	Clausager (in Saurola 1978)	Nestboxes
	Craig et al. 1979	Nestboxes
	Fitzner 1980 pers. comm. (see text)	Nestboxes
	Hamerstrom 1974	Nestboxes
	Hamerstrom et al. 1973	Nestboxes
	Heintzelman 1964, 1971	Nestboxes
	Heintzelman and Nagy 1968	Nestboxes
	Henderson and Holt 1962	Nestboxes
	Henny 1977a	Nestboxes
	Jones (in Byers 1980)	Nestboxes
	Nagy 1963	Nestboxes
	Stahlecker 1979	Nestboxes
	Stahlecker and Griese 1977	Nestboxes

Table 3.--Continued.

Species	Reference	Nest Type
Common Kestrel (*Falco tinnunculus*)	Bijleveld 1974	Nestboxes
	Cavé 1959, 1968	Nestboxes
	Hauri 1960	Nestboxes
	Kaeser 1957	Nestboxes
	Koning 1965	Nestboxes
	Krambrich 1968	Nestboxes
	Krambrich and Friess 1968	Wicker (?) Baskets
	Saurola 1978	Nestboxes
	Schmidt 1948	Nestboxes
European Hobby (*Falco subbuteo*)	Krambrich 1968	Wicker (?) Baskets
	Saurola 1978	Artificial Nests
Prairie Falcon	Boyce et al. 1980	Artificial Nests
	Fyfe and Armbruster 1977	Artificial Nests
Gyrfalcon	Schey (in Saurola 1978)	Artificial Nests
Peregrine Falcon	Cade and Dague 1979	Artificial Nests
	Fyfe (in White 1974)	Artificial Nests
	Hall 1955	Artificial Nests
	Mebs 1969	Wicker Baskets
Barn Owl	Lenton 1978	Nestboxes
	Marti et al. 1979	Nestboxes
	Millsap (in Call 1979)	Nestboxes
Screech Owl (*Otus asio*)	Henderson and Holt 1962	Nestboxes
	VanCamp and Henny 1975	Nestboxes
	Wilson 1925	Nestboxes
Flammulated Owl (*Otus flammeolus*)	Bloom 1978	Nestboxes
Great Horned Owl	Berger 1956	Artificial Nests
	Bohm 1977, 1980	Wire Baskets
	Doty 1974	Baskets
	Dunstan and Harrell 1973	Artificial Nests
	Postupalsky 1978a	Platforms
	Scott 1970, 1976	Platforms
Burrowing Owl (*Athene cunicularia*)	Collins and Landry 1977	Nestboxes
	Fitzner 1980 pers. comm. (see text)	Artificial Nests
	Orde (in Call 1979)	Nestboxes
Tawny Owl (*Strix aluco*)	Delmee et al. 1978	Nestboxes

Table 3.--Continued.

Species	Reference	Nest Type
Great Gray Owl (Strix nebulosa)	Berggren 1975	Artificial Nests
	Nero 1977	Artificial Nests
	Nero et al. 1974	Artificial Nests
	Persson (in Saurola 1978)	Artificial Nests
Ural Owl (Strix uralensis)	Persson (in Saurola 1978)	Artificial Nests
	Rouhiainen et al. (in Saurola 1978)	Artificial Nests
Saw-whet Owl (Aegolius acadicus)	Rever and Miller 1973	Nestboxes
Little Owl	Herren 1977	Nestboxes
	Knötzsch 1978	Nestboxes

structures, about 80 (i.e. 84 percent) report on separate projects. Seventy-six of the 95 references (80 percent) are from 1970 or later. Four main categories of artificial structures are discussed here: nestboxes, platforms, baskets, and artificial nests (i.e. nests carefully built by man to resemble natural nests).

NESTBOXES

The use of artificial nesting structures as research tools for studying the life histories, population dynamics, and contaminant loads of raptors is most refined with nestboxes. The most extensive study of this type was VanCamp's and Henny's (1975) work with Screech Owls in northern Ohio between 1944 and 1973. More than 4,249 nestboxes (as many as 985 in a single year) were checked during that 30-year period. As a result, the status, population dynamics, migration and dispersal patterns, breeding and wintering behavior, food habits, and pesticide loads of Screech Owls in that area are quite well-known.

The advantages of knowing the locations of nestboxes, the ease of checking them, and the long-term stability they provide to raptor populations have also been exploited by other researchers. Delmee et al. (1978) conducted a 15-year study of the population dynamics and breeding biology of Tawny Owls using artificial nest boxes. Some findings are difficult to obtain in any other way. For example, nest site and mate fidelity of Tawny Owls is nearly absolute (Delmee et al. 1978). The same is true of Screech Owls; one was banded at a box in 1945, retrapped there eight times through the years, and was killed within one-quarter mile of the box in 1958, thirteen years after being banded (VanCamp and Henny 1975).

Henny (1977a) set out about 300 nestboxes to attract nesting American Kestrels to an area sprayed with DDT, to an adjacent area, and to an unsprayed area during a controlled study of the effects of DDT and its residues on kestrel productivity.

Eggs were collected for pesticide analyses from 21 boxes in 1975 and from 51 boxes in 1976. (These figures also indicate the level of nestbox use.) It would have been very difficult to locate and monitor that many natural nests in the time available to Henny.

Using a similar research strategy, personnel of the Ecological Services Department of Battelle Pacific Northwest Laboratories (Battelle Boulevard, Richland, Washington 99352) put out 100 nestboxes in 1979 for small owls in coniferous forests as part of a long-term ecological monitoring program (Fitzner 1980 pers. comm.). Each nestbox is constructed so that when the owls are perched in the nest holes, all regurgitated pellets will fall onto a veranda to facilitate collection. Pellets will be collected and monitored for environmental contaminants. Craig et al. (1979) used 5 nestboxes to attract American Kestrels for the study of radionuclide concentrations in nestling raptors.

Other studies made possible by raptor use of nestboxes include the following. Nagy (1963) reported that six of nine nestboxes for American Kestrels were active in 1961 in an eastern Pennsylvania study area consisting of one-half square mile of farmland. Heintzelman (1964) reported on the summer food habits of this population. Heintzelman and Nagy (1968) reported on clutch sizes, egg hatchability, and sex ratios in 14 American Kestrel nesting attempts in nestboxes in the same area between 1959 and 1966 (the number of boxes available each year is not stated). Heintzelman (1971) also presented followup work suggesting that nestbox sanitation is not an important factor causing embryo mortality.

Hamerstrom et al. (1973) suspected that nest site availability was the limiting factor on American Kestrel populations in their harrier study areas in central Wisconsin where virtually no kestrel nesting had occurred prior to 1967. Of two nestboxes put up in 1967, one was used in 1967, and the other was used in 1968. Forty-eight more boxes were put up in 1968 and were maintained through 1972 (252 nestbox-years total). Kestrel activity was noted in 77 instances (31 percent) and 51 successful nests (20 percent) fledged 204 young.

In 1975 Stahlecker (1979) erected 25 nestboxes on wooden H-frame towers supporting a new electric transmission line crossing east-central Colorado. During 1975, 1976, and 1977 American Kestrel activity was noted at 12, 19, and 24 nestboxes, respectively (74 percent occupancy over 3 years), resulting in 172 young. Since only six natural kestrel nests occurred along the powerline route, this study clearly demonstrated the potential of nestbox construction as a mitigation measure along new powerlines. Henderson and Holt (1962) used nestboxes to facilitate their banding studies of Screech Owls and American Kestrels. Over a three-year period, 137 Screech Owls and 155 American Kestrels were banded in 200 nestboxes erected near Andover, Massachusetts.

The potential for use of nestboxes as a reclamation tool was shown by Cavé (1968) who in 1959 introduced 246 nestboxes into an area recently reclaimed from the sea in the Netherlands. The next year 109 pairs of Common Kestrels nested in the area. The same potential exists where strip mines or other areas with severe surface disturbance are reclaimed.

The frequent use of nestboxes in European countries to bolster Common Kestrel populations was reviewed by Saurola (1978). Denmark, Switzerland, Great Britain, the Netherlands, Germany, and many other countries have kestrel nestbox programs--some have been operating for up to 30 years! While most raptor nestbox programs in North America have been conducted to meet various research goals, nestboxes could be installed on a large scale with significant results whenever desirable. Bloom

(1977, 1978) lists as goals of a nestbox program the expansion of nesting habitat where no habitat presently exists and the reestablishment of such habitat where it has been eliminated. During the fall of 1976, Bloom erected 100 nestboxes in several habitat types in northeastern California. Of 67 useable boxes in 1977, fourteen (21 percent) were used by American Kestrels. Only 54 boxes were useable in 1978, but 18 of these (33 percent) were used by American Kestrels, and another housed a pair of Flammulated Owls.

Nestboxes have also been the standard nesting situation offered to captive kestrels to stimulate breeding (e.g., Willoughby and Cade 1964, Koehler 1969, Porter and Wiemeyer 1970, and Bird et al. 1976). Details concerning kestrel nestbox dimensions and construction can be found in Ross (1969) and Byers (1980).

Besides Delmee et al. (1978) on Tawny Owls and VanCamp and Henny (1975) on Screech Owls, three other nestbox studies involving owls are noteworthy. Lenton (1978) reports considerable initial success with conditioning Barn Owls to use large artificial nest boxes atop 24-foot wooden poles. Although this program was only one or two years old at the time, 7 of 30 boxes were in use. Marti et al. (1979) installed eight large nestboxes in 1977 and an additional 22 in 1978 in abandoned grain silos in northern Utah where Barn Owls had been roosting. Four of the eight available boxes were used by nesting Barn Owls in 1977. Twenty-four of the 30 boxes available in 1978 were used. Out of a total of 38 nestbox-years, 28 (74 percent) were occupied.

Artificial nestboxes buried in the ground are also readily adopted by Burrowing Owls. Collins and Landry (1977) built 30 nest chambers and burrows connecting to the outside and covered them with at least 6 inches of dirt in Orange County, California. The easily opened chamber provided ready access for growth and life history studies. Twenty of the 30 chambers (67 percent) were in use in 1975. Orde (in Call 1979) is experimenting with similar structures on the Pawnee National Grassland in northeastern Colorado. Since destruction of burrows is a primary cause of Burrowing Owl declines, and because these owls can live in concert with man if left alone, this technique indicates great potential 1) for promoting Burrowing Owl nesting in and adjacent to urban areas and 2) as a reclamation tool wherever needed.

Artificial Platforms

The most successful artificial platform programs are for Ospreys. Hundreds of structures have been erected for this species, often as a logical extension of the Osprey's ready acceptance of man-made nest substrates placed in their habitats for other purposes (e.g., channel markers, duck blinds, piles of crab traps, utility poles, docks, and pilings).

The earliest available reference to erecting artificial nesting platforms for Ospreys is Ames and Mersereau (1964). They erected three platforms in 1961 in southern Connecticut after most pairs had already chosen nest sites. Nonetheless, all three sites were immediately occupied, and in two cases eggs were laid within 72 hours. Twenty-one nesting platforms were erected in the same area in 1962 with the aid of a grant from the National Geographic Society (Peterson 1969). Nine of these were active in 1962, and 11 were active in 1963 for a total of 45 platform-years in the area and a 51 percent occupancy rate. Ames and Mersereau (1964) concluded that the platforms effectively protected the birds from predation and tidal flooding, but productivity of the entire population remained extremely low due to pesticide contamination (0.29 young per nesting for 157 nestings over four years).

In 1964 Reese (1965, 1970, 1977a, 1977b) began erecting artificial platforms for Ospreys along the coast of Chesapeake Bay in Maryland. Between 1964 and 1974 a total of 285 platform-years (mean = 26 platforms per year) were available to Ospreys Birds used 164 (58 percent) of these (Reese 1977b), an occupancy rate close to that obtained by Ames and Mersereau (1964).

Another successful artificial platform program for Ospreys in Michigan began in 1967 (Postupalsky 1978a, Postupalsky and Stackpole 1974). Between 1967 and 1977, 425 platform-years were available. The rate of occupancy was 55 percent (233 out of 425). The eleven-year means for productivity in natural nests versus artificial platforms were 0.6 and 1.2 large or fledged young per occupied nest, respectively. At one site, Fletcher Pond, the Osprey population was decreasing due to deterioration of existing nest sites, primarily snags resulting from the original man-created flooding. From a low of 11 pairs in 1966 this population increased to and stabilized at about 17 pairs by 1972, after 20 platforms were constructed in 1967. The platforms not only reversed a declining population trend, but also maximized productivity by reducing nestling loss due to nest blowdowns.

Equally encouraging results were obtained by Rhodes (1972, 1977) on the Glen L. Martin National Wildlife Refuge in Maryland between 1968 and 1972. The Osprey population on the refuge increased from four to six pairs before 1968 to 18 to 20 pairs in 1971 and 1972. The occupancy rate of artificial structures over the five-year period was 78 percent (75 nestings out of 96 platform-years), but productivity was less on the platforms (1.4 young per active nest) than at "natural" nest sites (2.0 young per active nest).

Two other large and long-term Osprey platform projects have been very successful but await quantitative analysis of results. In 1971 at the Eagle Lake Osprey Management Area (California) 15 live pine trees were topped. Spikes driven in around the circumference of the cuts provided stability for prospective nests. In addition, 20 artificial platforms supported by huge cedar poles were erected in the management area (Kahl 1972a, 1972b; Garber et al. 1974). One year later Ospreys used 12 of the 20 artificial structures (69 percent occupancy), but only one of the 15 topped trees. Henny et al. (1978a) reported 13 pairs of Ospreys using platforms at the Crane Prairie Osprey Management Area in Oregon, but no other follow-up on this project, which began in 1969 (Roberts 1969, 1970), was available for this review. The U.S. Forest Service could make a significant contribution to the raptor management literature by analyzing and publishing the data from their two Osprey Management Areas.

Kennedy (1977b) erected 20 platforms on the eastern and western shores of Chesapeake Bay in Virginia. Ten (50 percent) were active the year after they were erected. Sietke (in Saurola 1978) reported that nearly all of 25-30 platforms erected on powerline poles in Germany are used by Ospreys each year.

Fifteen platforms on Shasta Lake (California) had an occupancy rate of only 11 percent from 1977-1979 (five nestings in 45 platform-years) (Bogener 1979). In 1979 most of the limbs near these platforms were trimmed away at the suggestion of Detrich (1978b) in an effort to increase the occupancy rate. References to other smaller or unquantifiable Osprey artificial nesting platform projects are listed in Table 3.

Nesting on man-made structures by Bald Eagles is extremely rare. Abbott (1978) reported that two pairs of Bald Eagles nested on 100-foot high wooden observation towers at the U.S. Army Proving Grounds at Aberdeen, Hartford County,

Maryland, during the late 1950s and early 1960s. Postupalsky (1978a) cited two other such instances in the northeastern United States (Langille 1884) and in Alaska (Sherrod et al. 1976).

Similarly, only a few Bald Eagles have used artificial nest structures. Postupalsky (1978a, 1978b, 1980 pers. comm.) has witnessed nine nesting attempts on three different artificial structures through the 1979 nesting season. The first and only successes were in Michigan in 1977. One pair nesting on an Osprey platform in the Upper Peninsula fledged two young. Another pair fledged three young from a makeshift wooden pallet platform erected near Fletcher Pond to replace a fallen nest in 1969. Nelson (1978) reports a pair of Bald Eagles at one of his Golden Eagle platforms (see below) in 1977, but a nest was not built. The U.S. Forest Service has erected several platforms for Bald Eagles at Ruth Lake, Trinity County, California, according to specifications developed by Lamb and Barager (1978), but it is too early to evaluate the success of this project. Grubb (in Call 1979) built two tripod-type structures for Bald Eagles in Arizona. One was used the first spring that it was available, but the nesting attempt was unsuccessful.

Kulves (in Saurola 1978) reported that 20 platforms were erected for White-tailed Sea Eagles in Finland during the mid-1970s, but none had been used by 1977. Use of artificial nests (i.e. those carefully built to resemble natural nests) by Bald Eagles and the closely related White-tailed Sea Eagle is discussed elsewhere.

Another species that frequently nests on man-made structures not designed for that purpose (e.g., power poles, windmills, haystacks, stone chimneys of abandoned buildings, sheepherder monuments, etc.) is the Ferruginous Hawk. Perhaps the best designed raptor management research project involves the installation in late 1975 of 12 pairs of platforms for this species in an area near the Snake River Birds of Prey Natural Area in Idaho where no Ferruginous Hawks nested previously (Howard and Hilliard 1980). Each pair of structures consisted of one with a sun shade and one without about 150 yards from each other. Thus, 12 territories with artificial platforms were available from 1976 through 1979 (48 platform-years). Seven nestings by Ferruginous Hawks occurred during that time (15 percent occupancy), five of which were successful. In addition, ten nestings of Ravens (Corvus corax) occurred, eight of which were successful. The occupancy rate for Ferruginous Hawks and Ravens combined was 35 percent. No Ferruginous Hawks nested on the

several years by a pair of Swainson's Hawks. In 1975 Stahlecker (1979) erected 12 platforms on a new double crossbar H-design powerline in Colorado expecting use by prairie buteos. No raptors used the platforms during 1975, 1976, or 1977, but one pair of Ferruginous Hawks and one pair of Swainson's Hawks nested on the double crossbars.

Red-tailed Hawks have used artificial platforms installed for Golden Eagles in Idaho and Oregon by Nelson (1978) and Lee (1980) and for Ospreys at the Crane Prairie Osprey Management Area in Oregon (Henny et al. 1978a).

Artificial platform use by Golden Eagles is uncommon, but several instances are noteworthy. Call (1979) reports a successful nesting by Golden Eagles on the Pawnee National Grassland in northeastern Colorado, and Warburton (1972) reports at least one unsuccessful attempt on a platform in Puddle Valley, Utah.

The most significant developmental work on Golden Eagle nest structures has been done by Morlan Nelson of Boise, Idaho, as part of his consultant work with the electric industry (Nelson 1978, Nelson and Nelson 1977). He began testing the use of artificial nesting platforms for Golden Eagles in 1975. Noting that several species of birds, including Golden Eagles, Ospreys, Red-tailed Hawks, Ferruginous Hawks, and Ravens, were using steel and wooden transmission line towers for nesting, he reasoned that well-constructed nesting platforms on the towers would provide the needed nesting sites and lessen the chance of power outages that could result from nesting materials.

Working with the Bonneville Power Administration and the Idaho Power Company, Nelson erected six platforms prior to the 1977 nesting season on lines carrying up to 720,000 volts. All platforms were between 75 and 175 feet above the ground. Of the six nesting platforms installed, five nesting attempts were made. Three were successful (for a Red-tailed Hawk, Golden Eagle, and Osprey), while two were unsuccessful (for and Osprey and a Bald Eagle).

Nelson (1978) emphasized the importance of shade and protection from the wind in exposed sites. In hot desert areas, young Golden Eagles, Red-tailed Hawks, and Prairie Falcons may die from overheating if shade is not available for at least the head and shoulders. Shelter from the wind also appears to be beneficial to Golden Eagles and Red-tailed Hawks, but Ferruginous Hawks and Ospreys seem to have no requirement for protection from either the sun or the wind. This work is discussed further by Lee (1980). It has recently reached the implementation stage in Idaho and Oregon where 40 platforms are being erected on a new electric transmission line as an enhancement measure (Nelson 1980 pers. comm.).

The only other raptor for which use of artificial platforms is documented is the Great Horned Owl. Postupalsky (1978a) reports two nestings of Great Horned Owls on his tripod-type Osprey platforms in Michigan. Scott (1970, 1976) has attracted several pairs of Great Horned Owls to artificial platforms (actually shallow boxes).

BASKETS

Occasionally the distinction between artificial platforms and nesting baskets is difficult to make. For example, the duck nesting baskets monitored by Doty (1974), which have been used at least twice by Great Horned Owls, appear much like low platforms. Bohm (1977, 1980) had good acceptance of nest baskets by Great Horned Owls in central Minnesota. The nests were made of one-inch mesh chicken wire formed into a shallow cone. The cone was then lined with tar paper and provided

with a drainage hole at the base. An artificial nest consisting of twigs, leaves, and branches, with finer material near the top where the eggs would be laid, was built in each basket. Once the entire nest was complete, it was attached in a suitable crotch of a tree. Of 27 such nests available in 1977, 14 were used by Great Horned Owls and one was used by Red-tailed Hawks (combined occupancy rate of 56 percent). Productivity was slightly lower in baskets compared to natural nests.

A similar technique has worked well for Ferruginous Hawks. Call (1979) installed three wire baskets for Ferruginous Hawks in 1979 on the Pawnee National Grassland. Two of the three were used the same year. Fyfe and Armbruster (1977) reported that a major limiting factor for some raptors in Alberta appeared to be the lack of nest trees. Thus, in 1971 the Canadian Wildlife Service constructed and erected artificial wire baskets for Ferruginous Hawks in five areas where old sites had been destroyed (Fyfe 1975). Four of these were occupied in 1972. By 1975, 37 baskets had been erected, of which 22 were erected in former raptor territories and 15 were placed in grassland areas with adequate prey but no previous record of occupancy. Of the 37 baskets, a total of 16 (43 percent) had been occupied by 1975, indicating the effectiveness of this technique. The majority of the occupancy was in former territories, indicating that these should receive first priority for artificial nest structures (Fyfe and Armbruster 1977).

Wire baskets are also used to stabilize the rather flimsy nests of Everglade Kites in Florida (Sykes and Chandler 1974, Graham 1978, Kern 1978). It is interesting that most attempts to get this species to use the baskets are accomplished after natural nests are built and eggs are laid or young are present. Nests and eggs or young are simply moved from their original settings short distances into the baskets with near total success.

Wicker baskets have been used in at least two areas in Europe with success reported for three species. The most significant project was the placement of 15 willow baskets mostly in old pine trees in northern Germany for tree nesting Peregrine Falcons during the 1950s. Five or six of the baskets were used, as were at least four deer shooting platforms built in trees in the same general area. Krambrich and Friess (1968) report that pairs of European Hobbies and Common Kestrels have used baskets (presumably wicker) placed in trees for crows.

ARTIFICIAL NESTS

Nest sites developed by man to closely resemble natural nest sites are termed artificial nests in this review paper. The construction of artificial nests is much more common in Europe than in North America. Americans seem especially willing to place unnatural nestboxes, platforms, and baskets in the environment, a tendency that is arguable philosophically and worthy of full consideration as raptor management projects become less research oriented and designed more for widespread implementation.

Many artificial nests have been constructed as emergency measures after nests have blown down, either to save nestlings from the same year or to keep a territory active in subsequent years. For example, Dunstan and Borth (1970) reconstructed an active Bald Eagle nest that had blown down, thereby allowing two nestlings to fledge naturally. During the fall of 1969 a broken Red-tailed Hawk nest was rebuilt by Dunstan and Harrell (1973). Red-tailed Hawks used it in 1970, and Great Horned Owls fledged young from it in 1971. In 1976 Fitzner (1980 pers. comm.) fabricated stable bases for two Swainson's Hawk nests which frequently blew down. In each case a three-pronged crotch of a downed tree was supplemented with other sticks by tying

them on with bailing wire. The crotch was then wired into the nest tree. One of the two sites was used in 1978 and 1979. Craig and Anderson (in Call 1979) reconstructed a Golden Eagle nest that was blown down one year and was idle the following summer. Nesting resumed the year after the artificial nest was built.

Although some artificial nests might also be classified as nesting platforms, the intent in each of the following cases was to construct as natural a situation as possible. Haugh and Halperin (1976) report that artificial wooden ledges placed along the sloping banks of the Sagavanirktok River in Alaska have not been used by Peregrines or Gyrfalcons. Schey (in Saurola 1978) described the construction of an artificial nest for Gyrfalcons which was in use the summer after it was built. Hall (1955) and Cade and Dague (1979) provided shallow boxes filled with sand and gravel to Peregrine Falcons nesting on large buildings, primarily to provide the proper substrate for nest scraping. Boyce et al. (1980) replaced an abandoned Peregrine Falcon nesting ledge in northern California after it had fallen from the cliff. The steel ledge took 4 days to fabricate and install, but the natural-looking result was utilized the following summer by a pair of Prairie Falcons which fledged two young. In December 1979 William E. Lehman and Douglas A. Boyce excavated a ledge on a cliff in Humboldt County, California, which had been rated as a potential Peregrine site. A female Peregrine was observed incubating eggs on the new ledge in April 1980, four months after its excavation (Boyce 1980 pers. comm.).

One of the largest artificial nest construction programs involves Prairie Falcons along several rivers in Alberta. Fyfe and Armbruster (1977) describe the digging of nesting cavities for Prairie Falcons into cliffs that previously had few or no suitable nesting holes. This problem has also been noted in Colorado (Olendorff and Stoddart 1974) and in Washington State (Olendorff 1973).

In 1970 four of five nest holes dug for Prairie Falcons in Alberta were occupied by pairs; the fifth was used by a lone male (Fyfe and Armbruster 1977). The next year 8 of 12 holes were used by either Prairie Falcons or Canada Geese (Branta canadensis), the other target species of the program. Between 1971 and 1975 field crews from the Canadian Wildlife Service and the Saskatchewan Falconry Association dug over 200 nesting holes, about one-quarter of which were occupied during that period, occasionally even by Peregrine Falcons (White 1974). This program has been so extensive that systematic follow-up has been impractical.

In 1976 Fitzner (1980 pers. comm.) accomplished a similar result (though on a smaller scale) with Burrowing Owls in south-central Washington State. He dug seven burrows into sandy loam banks along intermittent streams. Each hole was dug 3 1/2 to 4 feet deep with a shovel, about halfway up 10- to 15-foot banks. Four of the seven burrows were utilized by owls the first year, but there has been no follow-up since that time.

A large-scale and long-term artificial nest program for Great Gray Owls has been conducted since 1970 in southern Manitoba and northern Minnesota (Nero et al. 1974, Nero 1977). About 60 artificial nests, which are barely discernable from natural ones, are currently checked and maintained each year. Unfortunately, neither of the papers cited above indicates how many of these nests are active each year, but Great Gray Owls and an occasional pair of Red-tailed Hawks have used them.

The Great Gray Owl has also received considerable attention in Europe. Persson (in Saurola 1978) has the most extensive program with approximately 100 artificial nests built since about 1972 in Sweden. Another 50 to 100 such nests have been built by others in the same area. Several raptors besides Great Gray Owls have also used these nests, including Common Buzzards, Goshawks, Ospreys, and Ural Owls.

Berggren (1975) documented the nesting of Rough-legged Hawks and Golden Eagles on artificial nests in Sweden. Also in Sweden, Helander (1975) documents three such nestings of White-tailed Sea Eagles.

Finnish ornithologists are also very active in building artificial nests of two types. Artificial Osprey nests (120 are now in place) closely resemble platforms, but they are built atop trees and are made to look like natural nests (Saurola 1978). Nests for Common Buzzards, Honey Buzzards, Goshawks, and Ural Owls are usually constructed of small sticks woven into the existing structure of branches to form a stable base. No wire, nails, or other man-made materials are used. The base is then topped with a nest built of naturally occurring vegetation (Rouhiainen et al. in Saurola 1978). Between 1975 and 1977, 239 artificial nests were available in the Paijat-Hame, Finland, study area. Sixty-five of these (i.e. 27 percent) were used by four species of large raptors (see above).

CLOSING REMARKS

Time constraints have prevented discussion in this paper of the appropriateness of each raptor conservation method. A number of publications do discuss the theoretical and philosophical aspects of raptor management. The more important of these found in the raptor literature or closely allied publications are mentioned below. However, an exhaustive search of the total ornithological and wildlife management literature for theories and philosophies which may apply to raptor management was not possible.

The general approaches to raptor management have been discussed by Nelson (1969a), Cade (1971, 1974b), Olendorff and Stoddart (1974), White (1974), Hamerstrom (1974), and Mallette and Gould (1976). Ratcliffe (1977) divides these approaches into three classifications.

The first involves controlling people and, of course, minimizing impacts. Fyfe and Olendorff (1976) discuss ways to minimize the direct impacts of man's individual activities on raptors. Newton (1979) gives an excellent review of the effects of human persecution on raptors. Others have begun direct research on thresholds of disturbance tolerated by raptors (White et al. 1979). These thresholds must be known before serious behavior modification programs (as discussed by Temple 1978c) can be researched and implemented for raptors. These thresholds also affect the choice between active and passive conservation of raptors (i.e. protection versus management) (see King 1978). Related discussion of the philosophies of total protection versus management of Peregrine Falcons is offered by Cade (1971, 1974b).

question, "What species do we want to manage for?" It is too easy to make fundamental errors, because what is good for one species may be devastating to another. We could easily promote the abundance of a certain raptor and thereby depress the faunal diversity of an area (see Snyder and Snyder 1975). Thus we must make plans and set goals (Ratcliffe 1977), not unlike those in many of the recovery plans for endangered species (Marshall 1978) or in California's statewide plan for raptor conservation (Mallette and Schlorff 1978), an approach that other States and countries should emulate.

It is only through complete, integrated approaches as discussed by Plunkett (1978) that we will achieve the best results. This has been said in many ways before. Olendorff and Stoddart (1974) call for a multi-faceted, penetrating research effort to synthesize quantitative data concerning raptor population dynamics, ecological impacts, management, and conservation. Galushin (1977) put it this way: "if man's influence on birds of prey is multi-factoral, a policy to protect them from extinction should also be multi-directional."

Examples of integrated management for birds of prey are becoming more commonplace as raptor conservation becomes more popular. The endangered species of the world are the greatest benefactors of such management (Plunkett 1978). Currently in the United States there are recovery teams for the California Condor, Bald Eagle (5 regional teams), Peregrine Falcon (4 regional teams), and Everglade Kite. Recovery plans are approved for the California Condor and two Peregrine Falcon populations (Eastern and Rocky Mountain (Southwest)). Draft plans from most other recovery teams for endangered raptors are in various stages of review.

Less formal but still excellent examples of integrated raptor management programs can be found as follows: for the Osprey--Gale and Forkis 1974, Garber et al. 1974, Henny 1977, Kahl 1971, Roberts 1969; for the Bald Eagle--Beebe 1976, Robards and Taylor No Date; for the White-tailed Sea Eagle--Helander 1975, 1977; for the Mauritius Kestrel--Temple 1977; for the Peregrine Falcon--Armbruster 1978, Burnham 1979, Cade and Temple 1977, Fyfe and Armbruster 1977, Lindberg 1975, 1977, Monneret 1978, Walton 1979a, 1979b; for the Eagle Owl--Broo 1977, 1978, Wayre 1970, 1975; and for various species--Chaney 1979, Mallette and Schlorff 1978, Olendorff and Kochert 1977, Olendorff and Zeedyk 1978, U.S. Bureau of Land Management 1979. Nearly all other projects involve narrower, single-method approaches to raptor conservation which collectively contribute significantly to the more integrated management programs.

It is readily apparent from the raptor management literature of the 1970s that the next decade will be another of tremendous progress. Three lines of thought outlined by Voous (1977) at the 1975 World Conference on Birds of Prey are still appropriate for action in the 1980s. First, birds of prey are naturally-provided and cheap biometers--indeed computers!--of the collective impacts, both positive and negative, of ecologically disruptive activities. This concept was presented very succinctly by Curry-Lindahl (1977). He stated that "...raptorial birds as the last links of food chains become important as indicators of well-balanced ecosystems, of landscape health and of environmental quality." Unfortunately, we have not quantitatively illustrated through basic research the practical applications (other than pesticide monitoring) of the concept of using birds of prey as indicators of the long-terms collective impacts of the many other major degrading environmental factors. This concept has both species and habitat management aspects that should be researched during the 1980s.

This will require the establishment of baseline population data, even where raptors are abundant. Voous (1977) suggests, as his second item for eventual action, that we should not just preserve the habitats of rare, threatened, or endangered raptors. An ecosystem approach is recommended, including the protection of at least one nature reserve in each ecosystem where raptors still occur in large numbers and diversity. A common thread in the raptor conservation literature is that habitat protection may be the best way to save raptors in perpetuity, a concept that must be woven into the very fabric of raptor management during the 1980s. There are many exemplary habitats which, like the Snake River Birds of Prey Natural Area, need protection and management.

Finally, there are smaller areas where birds of prey should be kept in and man should be kept out (Voous 1977). Such places may not harbor all of the components of a representative ecosystem, but they have unusually high raptor populations. Management areas, sanctuaries, and buffer zones strengthened by land acquisitions, administrative closures, and other available techniques should become the hallmark of integrated raptor conservation programs during the 1980s. Perhaps in this way we can minimize the use of captive breeding, artificial structures, artificial feeding, behavior modificiation, hacking, cross-fostering, egg manipulations, and surveillance to keep raptor populations at levels necessary to prevent their further endangerment and subsequent extinction. Nonetheless, we must stand ready with a complete repertoire of fully researched management techniques with which to tinker and save species.

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MANAGEMENT AND RESEARCH NEEDS IN WESTERN FORESTS AND GRASSLANDS FOR NONGAME BIRDS

John W. Mumma

Director
Wildlife Management Staff
Forest Service
USDA
Ogden, Utah

ABSTRACT

The indicator species concept needs considerable attention both by research and management, as implied in the National Forest Management Act of 1976. A national policy dealing with nongame birds is sorely needed; economic values, as they pertain to nongame birds, must be addressed in the 1980's. Intensified interagency cooperative relations is required for synchronization of data storage and retrieval efforts to help reduce the amount of duplication in these efforts. We also need stepped-up information and education efforts to highlight success stories and a definition of what the essential habitat components actually are-- either by life form groups and/or by species of birds. A hardback-bound book containing the findings expressed in the first symposium and the four national nongame bird workshops would be very useful to managers.

KEYWORDS: research needs, economic values, indicator species, habitat components, data storage and retrieval.

Good morning, ladies and gentlemen. I am pleased to be here to share the next few minutes with you covering some aspects of management and research needs for nongame wildlife habitat.

Before delving into the subject at hand, I would like to take this opportunity to compliment the other speakers on the program. They certainly represent a very distinguished group of experts in the Western United States dealing with nongame birds. My compliments also to Dick DeGraaf for his efforts in organizing the previous workshops in his capacity as Chairman of the Nongame Steering Committee.

In preparation for this discussion, many individuals were contacted, representing both management and research, to capture their thoughts on what the needs are for nongame birds. Interestingly enough, the one common denominator they all expressed was dollars. There is no doubt that additional funds are an essential part of any continuing program. I think the subject of funds would form the basis of an interesting panel in itself. Be that as it may, the attendance at this meeting is indicative of the fact that priorities are changing and that when you have to operate within existing budgets, there are ways and means in which jobs can be accomplished.

And while we are on the subject of economics, one area of need concerns the economic values of nongame animals. Many projects and plans utilize various approaches to economics, whether it is benefit/cost ratios, cost effectiveness, or other methods. One of the problems that biologists and managers are often confronted with is expressing wildlife values. Whether we like it or not, in this day and age, it is necessary to address the economics of various proposals.

Probably the other most consistent item mentioned dealt with the requirements contained in the National Forest Management Act of 1976. In some respects, the requirements are almost terrifying when one looks at the final Regulations published in the Federal Register of September 1979. For the first time, Forest land managers must look at the relationship of animals to their vegetative communities and indicate changes that will take place over time. Herein lies the biggest management need and, hence, a major research topic and this deals with the indicator species concept. A part and parcel of this is the diversity questions that must be dealt with.

The efforts that Jack Thomas and his co-workers made into the development of the managed forests in the Blue Mountains is one of the highlights of the 70's. It has certainly illustrated the knowledge to date of the relationships of many animals and furthered the concept of life forms. Much of the philosophies and postulated relationships need additional research for many habitats throughout the Western United States. Management is now asking for, and it behooves research to provide, the answers to questions being raised about - What if this type of vegetation is treated and what can be the expected animal response 20, 40, 100, and even 200 years from the present?

One question that needs to be answered is how we can actually improve habitat for various species. Interestingly enough, we recently contacted some people to request information on designing an ideal habitat mosaic or complex for certain species. We were informed that this information is not really known. Rather, what is known is that they occur in certain types. But how much, where, and in what arrangement is largely unknown. One exception that comes to mind is Ohmart and Anderson's work, largely in Arizona, in creating both vertical and horizontal mosaics. Efforts of the type of work they have done on the Colorado River is needed for the ponderosa pine type.

Dave Winn's work here in the Intermountain Region is certainly noteworthy. Projects underway on the North Slope Uinta Mountains, Sawtooth National Forest, Curlew National Grassland, and on the Bridger-Teton National Forest in Wyoming will help in our understanding complexities of the relationships between "critters" and their habitats. The results will be available in the near future. The program will be contained in WILD RAM (Wildlife Resources Analysis Model).

An additional component of this question concerns the minimum size of habitat essential to support a viable population of a species. This is necessary if we are to adequately address the indicator species concept. We suspect that true indicator species need additional study for various habitats in the country. Monitoring, as required by the National Forest Management Act, is needed. What type of monitoring, how and what frequency is needed? Is monitoring of vegetation in itself adequate? If not, what other avenues are there?

Another management need deals with the impacts associated with increased energy utilization. I am referring here to the dramatic, almost staggering increases in fuelwood utilization throughout the West as a supplement to heating fuels. What impact will this have on the cavity nesting birds and other species that utilize snags as an important component of their habitat?

I recently saw the figures relating to an estimate that 3.3 million cords of firewood were removed from the National Forests in fiscal year 1979. This is through free-use permits only and does not include commercial firewood utilization. This is roughly equal to seven million barrels of oil, or about a 12-hour supply of oil for the entire nation. Nearly one-half million free permits were issued and the Forest Service has noticed a dramatic increase the past several years in firewood consumption.

Quite naturally, the most accessible areas are the ones utilized the most. Certainly, we cannot advocate that all of the snag-dependent species must be relegated to inaccessible areas only. We may be forced to adopt some of the European practices on a major scale such as installation of nesting boxes. While this is not the most appealing to certain people, it may be the only recourse in those areas adjacent to urban areas heavily utilizing firewood. What the overall effects of moving toward more artificial nesting structures are is certainly deserving of research when one begins to wonder about the ramifications in terms of dependent species, i.e., kestrels, bats, etc.

One of the charges for managers is to integrate intensive snag management on at least the same scale as timber management. You have already heard that more intensive timber management is going to happen. It then behooves us to get on with the job of actually managing for snags. And, as much as I enjoy a fire- place, can we afford the true costs of this energy source? We are reminded of the statement that there is no free lunch!

Related to this is the fact that substantial efforts must be made on a national basis to inform the general public about the value of nongame birds as a part of the total ecosystem. I would suggest that more public information documents such as the publication, "Birds of the Upper Wind River Valley," are needed. The value of this type of a document is twofold: (1) It exemplifies cooperative efforts between the Audubon Society, university system, and National Forest managers; (2) It relates bird species to certain habitats and identifies locales within the area of where birders can go to see species at what time of year. We are looking forward to developing more of these. Major interpretive efforts on a national scale could be developed.

Other important components that need to be addressed are the use of a central computer storage file or data bank that contains up-to-date information on various studies and surveys completed. Many agencies currently have programs underway, but a better effort needs to be made nationally or regionally for coordination so that information is available to managers.

A national policy for federal agencies for nongame birds is sorely needed. How does this nation feel about nongame birds and, more specifically, what are the broad, long-range goals? I understand that an overall wildlife policy will be proposed by both the Agriculture and Interior Departments in March at the North American Wildlife Conference. While this is certainly applaudable, the Congress of the United States should enact legislation designed to enhance the recognition of nongame species. National nongame legislation has not been passed. However, I do believe it is forthcoming. Yet, all in all, the many agencies need to reach agreement on a basic policy dealing with nongame animals.

More positive information and education efforts need to be placed on habitat improvement programs designed for nongame birds.

Interestingly enough, some progress is being made at the state level to improve nongame programs. The Colorado program is definitely a model in this respect, much like Senate Bill No. 15 just passed in this session of the Utah Legislature. This Bill provides for an income tax checkoff and donation for a nongame program whichshould help provide additional impetus to the nongame program here in Utah.

Most of us are familiar with the Kirtland warbler-jack pine burning program. This is a good, positive nongame habitat management effort and, as additional ones are developed, we need to get the information out to the public. If we can develop an appreciation and understanding of the contribution these small critters play in the ecosystem and, at the same time, what we are doing about it, much support will follow. Management indicator species need to be identified and their population needs determined.

Lastly, a publication that would summarize the first symposium and subsequent four workshops is one of the biggest current needs. Some people have heard of one of the workshops or perhaps another one, but unless you were associated with the other workshops, you are probably not aware of them. For this session, we in the Intermountain Region prepared a resume' of the previous sessions. I would suggest that a hard-bound book compiling the information contained in the previous proceedings would be a tremendous asset, not only for the profession, but would be a welcome addition to the wildlife management curriculum at the college and university level. This, then, could form the basis for a course dealing with nongame birds.

Much of the discussion so far has centered on nongame birds, and I am reminded of a recent publication dealing with voles and their role in the management of coniferous forests. You probably have seen this or other ones talking about the functions that small mammals contribute to the functioning of an ecosystem.

I think this just touches the tip of the iceberg and would suggest that a followup conference to this workshop be held that would deal with small mammal habitat relationships.

As you can detect from the previous discussion, much work remains to be done in both management and research.

In closing, I am reminded of these words of Aldo Leopold:

"Conservation is a state of harmony between men and land. By land is meant all of the things on, over, or in the earth. Harmony with land is like harmony with a friend: You cannot cherish his right hand and chop off his left. That is to say, you cannot love game and hate predators: You cannot conserve the waters and waste the ranges: You cannot build the Forest and mine the farm. The land is one organism. Its parts, like our own parts, compete with each other and co-operate with each other. The competitions are as much a part of the inner workings as the co-operations. You can regulate them--cautiously--but not abolish them."

SUMMARY

Laurence R. Jahn

Vice-President
Wildlife Management Institute
Washington, D.C.

Fellow Resource Managers:

I am pleased to be here at this last of the regional workshops designed as a follow-through on the 1975 Tucson symposium on the management of forest and range habitats for nongame birds.

My purpose today is to examine, through an overview, the trail of these workshops, and focus on significant items laid along the way to satisfy the objective of this series of four regional workshops. That objective was to ensure that nongame bird habitat requirements are considered in forest and range management, and that a diversity of natural biological communities are maintained.

Those generating facts on species, populations and habitat requirements of birds have learned that the information must be woven into the resource or land management plan of resource managers to yield positive on-the-ground results.

That several laws--including the Multiple Use, Sustained Yield Act of 1960--have called for effective planning to assure multiple benefits from forest lands and rangelands is obvious. Only relatively recently have the responses of resource managers, biologists and other scientists broadened to ensure sustained yields of all forms of wildlife while planning and carrying out economic and recreational activities. This is because perspectives on planning for uses of forest lands and rangelands have been evolving slowly. The time frame, objectives and achievements are revealing, and help us understand the current transitional stage of management.

Prior to 1910. Emphasis was on selection of high-altitude vantage points for fire detection and prevention purposes.

1910-1940+. Functional resource "development plans" were framed, with emphasis on timber and domestic livestock. Coordination among individual functional plans left much to be desired at the field level.

After 1960. The Multiple Use, Sustained Yield Act of 1960 called for shifting from a single, functional, planning mold to a multifunctional frame that included water, timber, recreation, wildlife and forage resources. Conservation and management of the named resources was called for. Planning generally was done by one man with the information readily available. Plans largely were prepared from a forester's viewpoint, as only a few other resource professionals were employed then.

After 1970. The 1969 National Environmental Policy Act, the 1974 Forest and Rangeland Renewable Resources Planning Act, the 1976 National Forest Management Act and the recent implementing regulations covering forest lands and rangelands all call for interdisciplinary analyses of all "federal actions." The overall thrust is to identify in advance how the lands and waters in the National Forest System will be allocated and managed for a variety of uses. Natural values are to be given equal consideration with economic values in plans and actions.

In 1973, the U.S. changed from a one-objective system of national economic development (NED) to a two-objective system by adding the environmental quality (EQ) objective. This action was prompted by recognition that there are values important to society beyond dollar expression. Those values were given equal status with economic values. This was not completely new. For example, the U.S. Department of Agriculture never has calculated costs and benefits on soil and water management practices recommended in farm and ranch management plans. The two-objective system recognized this procedure and also was designed to help avoid the adverse impacts of strictly economic developments and costs to taxpayers of needed corrective and restoration actions. Such costs were highlighted when some Great Lakes fishes were removed from the markets due to chemical contaminants, when residents were forced to leave their homes along New York's Love Canal--an area where buried chemical wastes resurfaced--and in other cases as well. In all situations, economic benefit-cost analyses were misleading and incomplete; they ignored externalities and public views.

Now, within the framework of the EQ objective, both the biotic community and the ecosystem are to be accounted for in planning and carrying out proposed actions. In forests and rangelands, this means the status of birds and other living resources are to be used as barometers to reflect the integrity and health of those natural functional systems. This new demand provides biologists, foresters, and other resource managers with unique opportunities to broaden the scope of forest and range management, improve land management plans, and help assure multiple benefits on a sustained, yield basis.

1974. The first final environmental impact statements for unit plans on forest and rangelands were filed with the Council on Environmental Quality. Examination of those reports shows a general lack of information on adequate predictions of consequences of different land-use alternatives for living resources, such as fish and wildlife. None of these early plans offered concrete allocation of habitats or management direction specifically to meet the needs of nongame birds and other living resources.

1975. In May at the Tucson, Arizona symposium, a strong call was registered to recognize fully nongame bird habitat needs, as well as needs for other living resources, in land planning and management decisions. A bridge had to be built to connect the accumulating knowledge on birds and their life requirements to land-use planning and management procedures and actions. This bridge still is being worked on today. Important elements gradually being defined are quantified objectives and an accountability system for wildlife habitat in terms used easily by practical resource managers at the field level.

1979. The helpful landmark publication entitled Wildlife Habitats in Managed Forests was recently released. It provides the framework for information and procedures to help ensure input of wildlife needs into land-use planning and management decisions. Although the biological information is specific to the Blue Mountains of Washington and Oregon, the concepts, principles and procedures have universal application. That report is a substantial contribution resulting from research, management experiences and planning efforts during the "planning decade of the 1970s."

1980. The 1980s have been labeled the "action decade." This declaration is most appropriate for the topic being considered here. The identified concepts, principles and procedures for nongame birds and other living resources must be incorporated in every compartment and unit management plan for all forests and rangelands. During the opening session, Max Peterson stated that such action would be the central focus during his term as Chief Forester. Since his term is undefined, a target year of 1985--when all land management plans are to be completed on the National Forest System--is the time frame for registering accomplishments. But remember, the acid test will be the effectiveness of management applied on the ground.

This concentrated effort will require a high degree of coordinated teamwork among professionals and citizens--a process that we have seen previously only infrequently. Foresters, wildlifers and fishery specialists are urged to pool their knowledge and judgments to advance improved management of forests and rangelands for multiple outputs and benefits.

The concepts, principles and procedures for incorporating living resource needs into land-use plans, decisions and actions have been defined. Case histories on individual forests and rangelands reported at this and previous workshops provide clear

testimony of practical, workable approaches. Plans for individual national forests illustrate clearly the two general concepts in planning and managing wildlife habitats. They are:

1. Species richness; and
2. Featured species habitat maintenance and management.

Species richness allocations have been designated "Resource Production-Basic." Areas assigned to this category emphasize wood fiber and domestic livestock, with wildlife habitat at a prescribed level, such as sufficient habitat to maintain 50 percent of optimum wildlife population levels. By focusing on habitats required for feeding and reproduction, the land manager can reduce his considerations for hundreds of species to a relatively small number of life forms. For example, 379 species of land vertebrates were combined to 16 life forms in Oregon.

This is a critical simplifying approach that avoids overloading a resource manager with excessive demands in planning, decision making and implementing actions. Indicator species--those most sensitive to habitat manipulations--can serve as barometers for other species with similar but less-restrictive habitat needs. By using this life form-habitat requirement concept, a manager can make a decision with respect to wildlife, with the wildlife-commodity relationships identified clearly. The overall objective should be to maintain the maximum number of species at densities most closely reflecting established baseline community conditions.

In proceeding on this basis, each participant in the interdisciplinary planning team will face some difficult questions.

1. What was the "pristine" vegetative community? When? What was or is the "natural" condition? When?

Answers to these questions hinge on identifying the vegetative community and the disturbances subsequent to that specific time of reference. Several speakers emphasized difficulties in defining and reestablishing pristine or natural conditions of forests and rangelands. The problem is that such written records--usually fragmentary--span less than two centuries and photography less than 150 years. In-depth evaluations of landscape areas and plant communities are needed to piece together a firmer understanding of historic conditions.

2. A related second specific question is, how much old growth is needed? Where?

Here we may need to consider ecoregions or states as fundamental landscape units within which to identify all existing old-growth stands of each different plant community. How many of each are there now? Where do they exist? How many will not be subject to timber harvest and other conversions, such as those in national parks, wilderness areas, natural areas, monuments, wildlife refuges and other similarly designated areas? These communities should serve as some of the reference study areas where research is conducted to help define more precisely what is "pristine" and "natural," and to provide information needed to improve

the quality of data used in the planning-decision making-management matrix employed to manage forests and rangelands.

Management plans for forests and rangelands should show how points of concern for birds are accommodated. For example, in the Douglas fir forest type, there are four concerns for birds in stands managed for timber:

1. Shortening of the grass-forb and shrub stages;
2. Effects of an even-aged Douglas fir monoculture;
3. Drastic reduction or elimination of snags; and
4. Drastic reduction or elimination of old-growth (120+ years) forest.

Managers should address these and other similar concerns in management plans and environmental impact assessments and statements. They should clearly spell out why each concern is unwarranted. That preventative approach would be helpful in gaining citizen support for proposed management plans and in avoiding court reviews.

Quantity and quality of the contents of management plans rest on the basic data generated for each forest and range type or biotic community. That more or better data are needed for some communities was emphasized by a number of speakers.

Two items need constant attention to make the matrix system for land management planning, decision making and implementation function effectively.

1. The vegetative community classification and inventory systems must identify successional stages. Any system that fails to do this will severely limit capabilities to predict consequences of alternative management prescriptions. Current and future successional stages must be understood thoroughly.

2. Feeding and reproduction needs of individual species and groups of species must be identified. Using the best available information now should be acceptable in completing forest and range management plans. This approach is used elsewhere, such as in water pollution prevention and control programs.

The management plans developed using a matrix system must be monitored by law. Both quality control and research are needed to improve this relatively new system. Quality control is required to check on procedures and results. Research results are needed to evaluate predicted responses called for in management plans. Segregating cause-and-effect relationships in this feedback of information will aid in improving the effectiveness of the total planning-action matrix system. Research also should supply any added basic information needed on plant communities, wildlife species or groups, and their inter-relationships. Inputs on these items will strengthen the overall system. But keep in mind, the system functions continuously on the best information available.

Evaluating the vegetative stands within a community implies that the forester, range specialist, biologist or other resource manager reads the landscape and prescribes silvicultural or other management measures that will yield multiple benefits on a sustained basis. This means that the must have a firm understanding of each biotic community within the

area(s) of his or her responsibility. This demand will stretch the expertise of many resource managers, especially when they rotate stations on a short-term basis. The vehicle providing continuity in management efforts for a given compartment, unit, forest or range, as individual managers rotate stations, is the resource or land management plan. Its importance cannot be overstated.

That management prescriptions must be tailored to specific communities was emphasized by a number of speakers. One example illustrates the cardinal importance of this refined approach for intensive, integrated, multiple-benefit management.

Fire, both wild and prescribed, should be encouraged in lodgepole pine stands. On the other hand, fire protection seems essential to help assure old-age, long-cycling (500-1000 years) stands of spruce-fir. Fire by prescription for specified vegetative communities and stands is required in 1980, not a broad prohibition on use of fire for management purposes.

Throughout these workshops, we have learned about several different approaches being developed or used to meet legal demands for integrated multiple-benefiting resource management. Except for wetlands, there is no uniform national classification system and inventory procedure based on vegetative communities, that provides information in sufficient detail to link silviculture, range, wildlife and fisheries in a matrix system. This statement does not slight the continuous survey of timber resources initiated in the late 1920s and repeated at decade intervals. It has focused almost solely on timber and wood products.

The need for establishing a national landscape classification system and inventory procedure is emphasized by the signing of an interagency agreement by five federal agencies to work toward developing such a system. Last year, some states joined in that exploration. I invite you, with your practical experiences, to help develop that system and procedure. Bailey's ecoregions provide the frame. But within each ecoregion, we must be able to step down to local sites. A common data base is needed for many purposes. You can help fill that void. Having such a national classification system and inventory procedure in place would help strengthen capabilities to make improved resource management decisions. Whether those common procedures will be developed and in place to help meet the 1985 deadline is questionable. But that does not soften the pressing need for the national approaches. They hold promise for avoiding costly duplicative efforts.

We who have been privileged to be trained to develop knowledge through observation, research and management experience have heavy responsibilities to improve the management of resources, such as forests and rangelands. The public trust doctrine of law, as well as more-recent, specific, legal authorities, mandate that living resources be perpetuated for use and enjoyment by citizens. There is no choice, it must be done.

The question of how to proceed to incorporate more effectively the needs of living resources in resource and land management plans, decisions and actions is answered now. Proceedings from the 1975 Tucson symposium and its subsequent, closely associated four implementing workshops provide much of the critical information. The pressing task is to have the information applied to forest and rangeland management units throughout this country and others. Birds do not recognize political boundaries. They may breed in Canada and the United States, and winter in other countries.

Our challenge is to have the habitat management approaches for (1) wildlife species richness and (2) featured species applied broadly to assure sustained wildlife populations. Species richness measures should be preventative. Featured species measures also can be preventative for those animals having unique habitat requirements, and can help rescue threatened and endangered species and eventually remove them from legal critical lists.

The common ground for resource professionals and citizens is an effective program for management of living resources in forests and rangelands on the basis of different types of forest and range communities. That common base of understanding holds promise for launching combined efforts to seek funds and personnel to register accomplishments. Biological expertise must be available in adequate volume to ensure required inputs to interdisciplinary forest management teams and to forest and rangeland decision makers.

Finally, on behalf of the Steering Committee, let me express deep appreciation to the U.S. Forest Service, especially Dick DeGraaf and his associates, for accepting the recommendation to hold these regional workshops. Numbers of attendees at each workshop and subsequent requests for copies of the proceedings show clearly the interest in forest, range and wildlife management.

One further challenge and opportunity can be identified now, especially since the supplies of some regional proceedings are exhausted. One or more individuals should evaluate the merits of preparing and issuing a single volume on the concept, principles and procedures for carrying out an integrated forest-range-wildlife-fisheries planning and management system. It should be oriented to types of vegetative communities at the field level. Such a single volume assembled through the eyes of the field resource manager, and worded in his terms, would be most helpful.